GEI Consultants

Geotechnical
Environmental
Water Resources
Ecological

Final Remedial Investigation Report

Fulton Municipal Works Former Manufactured Gas Plant (MGP) Site

Brooklyn, New York

Order on Consent
Site No. 224051
Index No. A2-0552-0606

Submitted to:
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July 2012
Project 093020-1-1110

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Qualified Environmental Professional's Certification

I, David B. Terry, certify that I am currently a Qualified Environmental Professional as defined in 6 NYCRR Part 375 and that this Report was prepared in accordance with applicable statues and regulations and in substantial conformance with the DER Technical Guidance for Site Investigation and Remediation (DER-10) and that all activities were performed in accordance with the DER-approved work plans and DER-approved work plan modifications as discussed in this Report.

Date: July 6, 2012

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Abbreviations and Acronyms

AOC	Administrative Order on Consent
Alpha	Alpha Analytical Laboratory
ADT	Aquifer Drilling and Testing, Inc.
AST	Aboveground Storage Tank
ASTM	ASTM International
BAP	Benzo(a)pyrene
BASE	USEPA Building Assessment and Survey Evaluation
bgs	Below Ground Surface
Boart Longyear	Boart Longyear Environmental and Infrastructure Drilling
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
BUG	The Brooklyn Union Gas Company
CAMP	Community Air-Monitoring Plan
cf	Cubic Feet
cm/s	Centimeter per second
COPCs	Contaminants of Potential Concern
COPECs	Contaminants of Potential Ecological Concern
CSM	Conceptual Site Model
CSO	Combined Sewer Overflow
Cy	Cubic Yards
DUSR	Data Usability Summary Report
DNAPL	Dense Non-Aqueous Phase Liquid
EDR	Environmental Data Resources, Inc.
ELAP	Envrionmental Laboratory Approval Program
Ft	Feet
FOIA	Freedom of Information Act
FS	Feasiblity Study
FWRIA	Fish and Wildlife Resources Impact Analysis
GC	Gas Chromatograph
GEI	GEI Consultants, Inc.
GIS	Geogeographic Information System
GPS	Global Positioning System
GPR	Ground Pentrating Radar
HASP	Health and Safety Plan
HDR	HDR Engineering, Inc.
ID	Inner Diameter
IDW	Investigation-Derived Waste
KeySpan	KeySpan Corporation
LNAPL	Light Non-Aqueous Phase Liquid
LS	Land Surveyor

mg/kg	Milligrams per Kilogram
mg/m^3	Milligrams per Cubic Meter
MMcf	Million Cubic Feet
MG	Million Gallons
MGD	Million Gallons per Day
MGP	Manufactured Gas Plant
MOSF	Major Oil Storage Facility
MTBE	Methyl-tert-butyl ether
NAPL	Non-aqueous Phase Liquid
NAVD88	North American Vertical Datum 1988
NOAA	National Oceanographic and Atmospheric Administration
NPL	National Priorities List
NWI	National Wetlands Inventory
NYC	New York City
NYCDEP	New York City Department of Environmental Protection
6NYCRR Part 375	Title 6, Chapter 100, Part 700-705, Subpart 375-6 of the New York State Code of Rules and Regulations
NYSASP	New York State Analytical Services Protocol
NYSAWQS	New York State Ambient Water Quality Standards, Criteria and Guidance
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
ORP	Oxidation/Reduction Potential
PAH	Polycyclic Aromatic Hydrocarbon
PBS	Petroleum Bulk Storage
PCB	Polychlorinated Biphenyl
PCE	Tetrachloroethene
PDA	Personal Data Assistant
PDI	Pre-Design Investigation
PEL	Permissible Exposure Limit
PID	Photoionization Detector
OSHA	Occupational Safety and Health Administration
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance/Quality Control
QHHEA	Qualitative Human Health Exposure Assessment
RAP	Remedial Action Plan
RI	Remedial Investigation
RIWP	RI Work Plan
ROW	Right-of-Way
Sanborn	Sanborn Fire Insurance Map
SC	Site Characterization
SCOs	Soil Cleanup Objective
SVI	Soil Vapor Intrusion

SVOC	Semi-volatile Organic Compound
TAL	Target Analyte List
TestAmerica	TestAmerica Laboratories
TCE	Trichloroethylene
ug/m^3	Micrograms per Cubic Meter
UST	Underground Storage Tank
USACE	United States Army Corps of Engineers
USDOT	United States Department of Transportation
USFWS	United States Fish and Wildlife Service
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOC	Volatile Organic Compound

Executive Summary

On behalf of National Grid, GEI Consultants, Inc. (GEI) conducted a Remedial Investigation (RI) and prepared this RI report to describe environmental conditions at the Fulton Municipal Gas Works former manufactured gas plant (MGP) (former Fulton MGP; the Site). National Grid is responsible for conducting the RI and clean-up related activities at this Site because it acquired successor companies to The Fulton Municipal Gas Company, which constructed and operated the former MGP. The RI was conducted in accordance with an Administrative Order on Consent (AOC) and Administrative Settlement Index No. A2-0552-0606 between the New York State Department of Environmental Conservation (NYSDEC) and KeySpan Corporation (Keyspan), National Grid's predecessor, and was conducted in accordance with the NYSDEC-approved Final Remedial Investigation Work Plan (RIWP) and RIWP Addenda. Field activities were performed between April 2008 and May 2011.

The Site is located in the Gowanus neighborhood of Brooklyn, New York, adjacent to the Gowanus Canal (Figure 1). The canal was created by channelizing Gowanus Creek and filling the adjacent wetlands complex in the mid-1800s for the development of South Brooklyn. The Gowanus Canal and surrounding area have supported industrial and commercial activities for approximately 150 years. The Site and adjacent areas are currently zoned for manufacturing use (M1-2 and M2-1).

The former Fulton MGP manufactured and provided gas for use by businesses and residences between circa 1879 and 1929. Following decommissioning, the property was subdivided into five properties and sold by the Brooklyn Union Gas Company (BUG), a predecessor company to KeySpan, between the mid-1930s and 1940s. For purposes of the RI, the five properties were assigned parcel numbers (I through V); their current uses are described below.

- Parcel I: A warehouse being renovated into a movie studio
- Parcel II: Thomas Greene Playground (paved playground, Double "D" Pool, and handball court areas)
- Parcel III: School textbook warehouse
- Parcel IV: Construction lay down, truck maintenance and roll-off bin storage area
- Parcel V: Rock climbing gym and miscellaneous goods warehouse

In addition to the footprint of the former Fulton MGP, the investigation encompassed three additional parcels (Parcels VI, VII, and VIII).

The RI evaluated the nature and extent of potential impacts from the MGP operation as well as potential human health and ecological risks. Tar, commonly called coal tar, was a by-product of manufactured gas production. Coal tar is a dense non-aqueous phase liquid (DNAPL), with a density greater than water. MGP-related tar and its chemical constituents were the primary focus of the RI. The Site also included petroleum storage and gas oil/naphtha tanks, which constitute potential areas of environmental concern. Wastes associated with the former gas purification processes and lead related to lead-based paints can represent potential environmental concerns at former MGP sites, although purifier materials were not encountered during the RI.

The RI delineated the lateral and vertical extent of impacts associated with the former MGP. Potentially mobile DNAPL tar was observed at various depths beneath Parcels I, II, III, IV, VI, and adjacent to the eastern and western Gowanus Canal bulkheads on Parcels I, VI, and VIII. Much of the tar at Parcel III appears to be contained in the holder foundation – at least with respect to shallow tar.

Tar-related impacts were not encountered on Parcel V. On Parcel VII, tar impacts were limited to a 5-foot-layer of sheen deeper than 60 feet. Tar impacts and shallow petroleum impacts, likely associated with the former Fulton MGP, were present beneath the building at Parcel I. The deepest tar-related impacts were encountered beneath Parcel VI at approximately 128 feet below ground surface (bgs).

Shallow groundwater passing through tar- and petroleum-impacted soil is transporting dissolved phase volatile organic compounds (VOCs) and light end polycyclic aromatic hydrocarbons (PAHs) (e.g., naphthalene) toward the Gowanus Canal.

MGP-related tar has been identified in the Gowanus Canal sediments. It is present at a shallower depth along the western canal bulkhead than beneath the eastern canal bulkhead. The origin of all tar in the Canal sediments is unclear, but there are at least three potential sources. One potential source is subsurface migration from Parcels I and VI of the study area. The second is residues from tar spills and/or leaks from vessels, tanks, and piping that may have occurred while the plant was operating, as well as barging activities, all of which may have caused releases to the sediments. The third is from potential migration in the sediments from other downstream sources (the Flushing Tunnel at the head of the canal pulled water from Gowanus Bay toward the Canal headwaters from 1911 to 1960, creating a flow direction opposite of today's flow toward Gowanus Bay).

Tar and oil tanks with two overflow pipes to the canal are depicted in historic maps and also may have contributed to impacts in the canal. The most obvious shallow subsurface impacts on Parcels I and VI are petroleum impacts while most of the potentially mobile tar is below the bottom of the canal, thus suggesting limited subsurface migration pathways to the canal itself.

Observations of tar impacts originating at the inland parcels demonstrate migration pathways through the soils toward the canal but with a deepening vector (i.e. the tar migrated downward as it spread laterally).

Elevations of tar in canal sediments and adjacent subsurface soil do not consistently support either a lack of tar migration from Parcels I and VI into canal sediments, or migration of tar from sediments toward the canal bulkheads. This is probably a function of sediment movement caused by flushing tunnel operations.

The distribution of tar in canal sediments and in nearby soils is complex and does not clearly demonstrate the direction of all tar movement. At least some tar migrated from subsurface soils into the canal sediments and some also may have migrated from the sediments back into subsurface soils. Flow conditions in the canal have varied significantly over the past several decades and it is possible that tar migration in both directions has taken place as a result of changes in the operation of the Flushing Tunnel. The extent and magnitude of tar in the Canal sediments was probably influenced by the former Flushing Tunnel operation, which historically drew water up the Canal from Gowanus Bay and more recently, pulled water from Buttermilk Channel on the East River and pushed water down the Canal to Gowanus Bay.

A qualitative assessment of potential human exposures found that current users at each parcel have a very limited potential to contact any of the residual contaminants associated with the former Fulton MGP and; therefore, under current conditions, the environmental impacts pose no risk of harm to health for humans. However, potential future utility and construction workers may contact contaminants in subsurface soils at each of the parcels and beneath the streets during excavation activities. There is a potential risk of harm to these workers performing utility repairs or future construction activities from exposure to contaminated subsurface soil, groundwater, and soil vapor.

An evaluation of potential risk to the terrestrial ecology found that lack of habitat, an urban setting, and no exposure routes to terrestrial wildlife (through groundwater or soil), result in minimal potential ecological risk from MGP-related impacts. The ecological assessment did not consider potential aquatic risks because these are being separately addressed under a Superfund study administered by the United States Environmental Protection Agency (USEPA).

GEI, on behalf of National Grid, has already used the RI data and information in this report to develop a Pre-Design Investigation (PDI) Work Plan. The PDI will generate data to support design of a barrier wall along the canal. Regardless of tar sources and mechanisms of emplacement, the barrier wall is intended to prevent potential migration of non-aqueous phase liquids (NAPL) into, or out of, the canal. The PDI work plan has been approved by NYSDEC.

The overall nature and extent of MGP-related impacts has been defined and the remedial investigation is complete. Following NYSDEC and New York State Department of Health's (NYSDOH) approval of this report, we recommend that a Feasibility Study (FS) be prepared for Parcels I through VIII, with the exception of Parcel V. Parcel V lacks MGP-related impacts and we recommend no further action for this parcel.

1. Introduction

On behalf of National Grid, GEI Consultants, Inc. (GEI) conducted a remedial investigation (RI) at the former Fulton Municipal Works manufactured gas plant (MGP) (former Fulton MGP; the Site) in Brooklyn, Kings County, New York. National Grid is responsible for conducting the RI and clean-up related activities at this Site because it has acquired successor companies to The Fulton Municipal Gas Company, which constructed and operated the former MGP. This RI report describes the work performed for the RI, the environmental conditions encountered, and the relevance of the environmental findings pertaining to the nature and extent of Site-related impacts and potential risks to human health and the environment.

The RI was conducted pursuant to the executed modification to the multi-site Administrative Order on Consent (AOC) and Administrative Settlement [Index No. A2-0552-0606] between National Grid and New York State Department of Environmental Conservation (NYSDEC), dated August 7, 2007. The RI was also conducted in accordance with applicable guidelines of NYSDEC and New York State Department of Health (NYSDOH) including:

- New York State Department of Environmental Conservation, *DER-10 Technical Guidance for Site Investigation and Remediation* (2002 and 2010).
- New York State Department of Health. 2006. *Guidance for Evaluating Soil Vapor Intrusion in the State of New York.* October 2006.

The former Fulton MGP is referenced as Site No. 224051 in the AOC and the NYSDEC's Environmental Remediation Database.

Figure 1 shows the location and footprint of the former Fulton MGP. Figure 2 depicts the former MGP footprint, current parcel ownership, and the extent of the RI study area. The former Fulton MGP occupies five properties (Parcels I through V in Figure 2) between Douglass and Sackett Streets on the east side of the Gowanus Canal in Brooklyn, New York. As discussed below in subsection 1.2.1, Parcels I, III, IV and V are owned by private entities and Parcel II (Thomas Greene Playground) is owned by the City of New York.

Prior to the execution of the AOC, NYSDEC completed a site characterization (SC) of the former Fulton MGP within Thomas Greene Playground and adjacent public street right-of-way (ROW) during April and May 2007. NYSDEC issued the SC Report for the former Fulton MGP in September 2007. The SC findings are discussed in subsection 1.6.

Two other investigations associated with the Gowanus Canal involved work performed on the footprint of the former Fulton MGP, as follow:

- National Grid [formerly KeySpan Corporation (KeySpan) Gowanus Canal Investigation conducted between October 2005 and August 2006.

- United States Environmental Protection Agency (USEPA) Gowanus Canal Remedial Investigation conducted between January and December 2010.

A summary of canal investigation findings that are pertinent to the former Fulton MGP is provided in subsection 1.6.

The RI field activities were completed by GEI and GEI's subcontractors between April 2008 and May 2011. The RI activities were completed during ten separate mobilizations that were required to secure access with private property owners and to address RI Work Plan (RIWP) Addendum scopes of work requested by NYSDEC. The mobilizations are summarized below in subsection 1.1. RI activities were completed in general accordance with the NYSDEC-approved work plan and addenda (see subsection 1.1).

The remainder of Section 1 discusses the RI objectives and scope (subsection 1.1), presents a description of the RI parcels, current uses, and the MGP history (subsection 1.2), discusses the physical and environmental setting of the RI study area (subsection 1.3), and presents a summary of environmental search records pertaining to the RI study area (subsections 1.4 and 1.5), and discusses previous investigations (subsection 1.6).

Section 2 describes the methods and procedures applied during the RI. Section 3 discusses the geology and hydrogeology underlying the RI study area. Section 4 describes the nature and extent of impacts related to the Fulton MGP. Section 5 discusses the fate and transport of chemical constituents and tar. Section 6 provides a Qualitative Human Health Exposure Assessment (QHHEA). Section 7 presents the Step I Fish and Wildlife Resource Impact Assessment (FWRIA). Section 8 presents a conceptual model for the RI study area. Conclusions and recommendations are provided in Section 9.

1.1 Remedial Investigation Objectives and Scope

The purpose of the RI was to generate sufficient data to define the nature and extent of soil, soil vapor and/or groundwater impacts associated with the former Fulton MGP operations. The RI also utilizes the findings of the investigation to evaluate the potential risks to human health and the environment through development of a QHHEA and a FWRIA.

To fulfill the purpose, several objectives were established, as follow:

- Identify and investigate potential historic MGP structures.
- Characterize the hydrogeology of the RI study area.
- Characterize the extent of the meadow mat beneath the Site.
- Identify, quantify, and delineate MGP-related chemical impacts such as volatile and semi-volatile organic compounds (VOCs and SVOCs, respectively) and inorganic compounds, such as cyanide; compare their concentrations to NYSDEC standards.
- Identify, quantify, and delineate non-aqueous phase liquid (NAPL) in subsurface soil and groundwater.
- Evaluate potential vapor intrusion of MGP-related compounds into on-site buildings.
- Evaluate the potential for off-site migration of MGP-related NAPL and chemical compounds.
- Develop a QHHEA to evaluate potential risk to humans.
- Develop a FWRIA to evaluate the potential for impacts to wildlife resources at the Site.

To meet these objectives, a number of RIWP and RIWP Addendum scopes of work were developed and approved by NYSDEC, as follow:

- Final RIWP dated March 2008.
- Final RI Addendum No. 1 dated July 20, 2009.
- Final RI Addendum No. 2 dated October 22, 2010.
- Final Revised RI Addendum No. 2, dated February 2, 2011.
- Addendum to Final Revised Remedial Investigation Addendum No. 2, Proposed Boring in the Nevins St. Right-of-Way, dated March 30, 2011.
- Field Decision Confirmation Form [Final Revised RI Addendum No. 2] dated April 13, 2011.

The NYSDEC approval letters and field decision confirmation form are included in Appendix A.

The RIWP and Addendums scopes of work were completed during ten separate mobilizations, as presented in the following table.

Mobilization	Work Plan Scope(s)	Location(s)	Activities
1. May to June 2008	Final RIWP	Parcel II Public Street ROWs	Parcel II: soil borings drilled/ sampled, wells installed/sampled, hydraulic conductivity testing completed, soil vapor point installed/ sampled Public Street ROWs: soil borings drilled/sampled, wells installed/ sampled
2. July to August 2008	Final RIWP	Parcel I Public Street ROWs	Parcel I: soil borings/sampled drilled, wells installed/sampled, soil vapor points installed/sampled, indoor and outdoor air sampled. Public Street ROWs: soil borings drilled/sampled, wells installed.
3. March 2009	Final RIWP	Parcel I	Re-sampled soil vapor, indoor and outdoor air during heating season.
4. May to June 2009	Final RIWP	Parcel I Parcel IV Parcel VI Public Street ROWs (Parcels I, III, V)	Parcel IV: soil borings drilled/ sampled, wells installed/sampled, soil vapor points installed/sampled, and outdoor air sampled. Parcel I: Groundwater samples collected. Public Street ROWs (Parcels I, III, V): soil borings drilled/sampled, wells installed, groundwater samples collected.
5. July to August 2009	RIWP Addendum No. 1	Public Street ROWs	Soil borings drilled/sampled, wells installed
6. September 2009	Final RIWP RIWP Addendum No. 1	Parcel I to VI Public Street ROWs	Groundwater gauged; samples collected
7. January to April 2010	Final RIWP	Parcel III Parcel V	Parcels III/V: soil borings drilled/sampled, temporary wells installed/sampled, soil vapor points installed/sampled, and outdoor air sampled.
8. October to November 2010	Final RIWP Addendum No. 2	Public Street ROWs	Soil borings drilled/sampled.
9. January to February 2011	Final Revised RI Addendum No. 2	Parcel VIII Public Street ROWs	Soil borings drilled/sampled, monitoring wells installed.
10. April to May 2011	Final Revised RI Addendum No. 2	Parcel VII Public Street ROWs	Soil borings drilled/sampled, monitoring wells installed/sampled, groundwater gauged, hydraulic conductivity testing completed.

GEI also reviewed and evaluated the findings of previous investigation activities conducted by GEI, USEPA, NYSDEC and others within and adjacent to the RI study area. These previous investigations are identified and summarized in subsection 1.6 and pertinent findings are incorporated into Section 4.

1.2 Site Description

The former Fulton MGP occupied five properties located between Douglass Street and Sackett Street, and between the Gowanus Canal and 4th Avenue, (Parcels I through V as shown in Figure 2). Representative photographs of the Site are provided in Appendix B. Parcels VI, VII, and VIII in Figure 2 represent off-site areas of investigation. Figure 3 depicts the locations of explorations associated with the RI.

The Site is located within a dense urban area of mixed manufacturing, commercial, industrial, open-space (Thomas Greene Playground), and residential land use (Figure 4). The New York City Department of City Planning has designated the area as a light manufacturing zone (M2-1 and M1-2).

1.2.1 Fulton MGP and RI Study Area History

The history of the former Fulton MGP and surrounding area was developed through the review of selected historical maps, photographs, newspaper articles; historical Brooklyn Union Gas Company (BUG) drawings, available Sanborn Fire Insurance (Sanborn) maps, and information presented in previous reports. Historical drawings, photographs, and Sanborn maps are included in Appendix C.

1.2.1.1 Pre-MGP History

The area surrounding the Site and the Gowanus Canal was originally part of the former Gowanus Creek and associated wetlands and was first developed by Dutch settlers for farming and fishing during the late 1600s. By 1767, Gowanus Creek and its tributaries were dammed and developed for the operation of mills by the Dutch (Hunter Research, Inc., et al., 2004). John Freeke's (Freeke's) Mill Pond was located at the head of the current Gowanus Canal and extended under the majority of Parcel I, Parcel VI and the northern corner of Parcel II. The location of Freeke's Mill Pond is shown in Figure 5. The mill pond extended to the south of the former Fulton MGP.

In 1848, the State of New York authorized construction of the Gowanus Canal as well as the draining and filling of the wetlands of South Brooklyn, so additional development would be possible (New York City Department of City Planning, 1985). The Gowanus Canal was constructed between 1853 and 1869 and was designed as a conveyance channel for barges. The former Gowanus Creek was widened and deepened for one and one half miles from the bay to Butler Street (Brooklyn Historical Society, 2000) (Figure 1). It was widened to approximately 100 feet and was deepened to approximately 5 feet below the low tide mark throughout its entire length (Richards, 1848). Bulkheads were created along the Canal and the wetlands behind the bulkheads were filled. By 1869, the Gowanus Canal was completed with the current street configuration surrounding the Canal.

The canal supported transport of bulk materials such as coal, petroleum, asphalt, and lumber, as well as the rapid growth of industry in Brooklyn and surrounding areas. Consequently, the land use adjacent to Gowanus Canal reflected this industrialization (Figure 4).

1.2.1.2 MGP History

The Fulton Municipal Gas Company was incorporated in March 1879 (Murphy, 1995). The MGP was constructed the same year. The Fulton Municipal Gas Company operated the MGP from 1879 until it merged with six other MGP facilities to form BUG in 1895 (Murphy, 1995). The MGP continued making gas until 1929 (under ownership of BUG).

As depicted on an 1886 Sanborn map, the early coal gas production facilities were located at Parcel I and consisted of a retort house, an engine room, condenser rooms, and a gasoline house (Appendix C). Two relief gasholders, a governor house, and purification facilities were located to the southeast across Nevins Street on Parcel III and Parcel IV. The gasholders were built in 1878 (New York State Archives, 2009). Both holders were constructed with two lifts and were rated for 252,000 and 284,000 cubic feet (cf) capacities, respectively. Both were constructed with subsurface brick tanks and concrete foundations (New York State Archives, 2009).

A hydrogen tank (gas holder), a purge tank, and naphtha tanks were located at Parcel II. The gasholder was constructed in 1882 by the Fulton Municipal Gas Company. The holder had a 100,000 cf capacity and consisted of two lifts. The holder was constructed with a subsurface steel tank and had a concrete foundation (New York State Archives, 2009).

In 1887, the remote distribution gas holder at Parcel V was built by the Bartlett Hayward & Company. The holder was comprised of three lifts, a subsurface brick tank on a concrete foundation, and was rated for 985,000 cf capacity. According to a Brooklyn Daily Eagle newspaper article, the holder was constructed to a depth of 28 feet and was the largest holder of its time.

In 1895, the Fulton Municipal Gas Company and others merged to form BUG, a predecessor to National Grid. The 1904 Sanborn indicates that the MGP was referred to as “The Brooklyn Union Gas Company-Fulton Municipal Branch”. According to the 1904 Sanborn maps, the gas production facilities at Parcel I remained relatively unchanged from 1895 with the exception of the addition of an oil storage tank, underground tar/oil tanks with overflow pipes to the canal (1897 BUG drawing and 1915 Sanborn Map), and an aboveground tar separator located on an elevated trestle. At Parcel II, two circular oil tanks (Tank No. 7 and No.8) were present and the purge tank was absent from the 1904 Sanborn map. Two additional underground gas oil tanks and one naphtha/gas oil tank were depicted at Parcel II (1904 Sanborn Map). At Parcel V, the remote holder is shown along with accessory buildings including a boiler, two engine/blower houses, and a coal shed on the 1906 Sanborn map. The 1906 Sanborn map also depicts four driven wells connected to an iron water tank on Parcel V.

The 1904 Sanborn Map also illustrates the presence of a “City Pipe yard” at the northern end of the Canal. Parcel VII covers the eastern portion of the former pipe yard. The pipe yard was converted to a general storage area by 1915 and identified as “D.C.W. Borough of Brooklyn”. The pipe yard may have used tar-based coatings. There is a building on this parcel with a circular structure labeled “Tank Below Floor Level” (Figure 6). This building is a powerhouse for the flushing tunnel system.

By 1915, the MGP appears to have converted to water gas production as evidenced by the addition of generators and conversion of the retort house to a generator house at Parcel I (Figure 6). Tar and oil tanks are identified on the 1915 Sanborn Map. An 1897 BUG drawing of the same tanks includes two overflow pipes from the tanks to the canal.

The footprint of the BUG property expanded to encompass the northern half of Parcel II and the area to the east of Parcel IV by 1922 (BUG Mortgage, 1922). The expanded footprint of the MGP and BUG property is evident in a 1924 aerial photo (New York City [NYC] Geographic Information System [GIS], 2011), provided in Appendix C. Nine circular tanks and buildings were present to the northeast of the former holder at Parcel II. A number of outbuildings are depicted on the northern portion of the Parcel. Figure 6 provides a summary of the expanded footprint of the former BUG property. The 1924 aerial photograph is provided in Appendix C.

The Fulton Municipal Works MGP had an annual gas production of 2.7 million cubic feet (MMcf) in 1920, 2.5 MMcf in 1925, and 2.8 MMcf in 1926 according to historical BUG information. Gas production at the Fulton MGP decreased to 1.6 MMcf in 1927 and was just 0.04 MMcf in 1928. Gas production information was not available for the Fulton MGP after 1928. The MGP was likely, decommissioned as larger MGPs in the BUG system began operation. The Fulton MGP structures are absent from the 1938 Sanborn map (Appendix C).

Following decommissioning, BUG sold the Fulton MGP properties between 1938 and 1948. The history of property sales is discussed by parcel in subsection 1.2.1.4. A summary of post-MGP property information is provided below in subsection 1.2.1.4.

Since sale of the MGP properties by BUG, National Grid and its predecessors have not had use and/or control of the former MGP properties.

1.2.1.3 Potential Sources in the Study Area

There are numerous potential NAPL source areas in the Fulton Study area. These potential sources include former gas holders, former oil and fuel tanks, the tar process area, the former pipe yard at the northern end of the canal, and downstream portions of the canal itself.

The Fulton site and surroundings were an industrial, manufacturing, and commercial area during the MGP operating era. Coal tar was likely sold to other local users, who generated coal-tar related products, such as coatings and creosote (e.g., for wood poles or marine pilings). The former City Pipe Yard(1904 Sanborn) is an example of a local company that likely used coal tar in their product manufacturing process. The Texas Committee on Environmental Quality found that tar-based coatings were used in pipe yards in Texas and similar bituminous coatings are still used today to coat pipes. Therefore, the pipe yard at the head of the Gowanus Canal represents an example as a source of DNAPL tar not associated with the former Fulton MGP site.

An oil terminal was constructed at 510 Sackett Street in 1946, according to the 1950 Sanborn Map, which also indicates the operator was the Supreme Oil Terminal Corporation. By 1965 the terminal became the Bayside Fuel Oil Depot Corporation. According to the company website (http://baysidedepot.com/), the Sackett Street terminal was closed in 2005. Subsection 1.4.2.3 (below) provides details regarding a number of spill events at this Site on the west side of the canal, across from Parcel 1. This oil terminal is a potential source of NAPL impacts in the canal.

A detailed study (GEI, 2003) of other industry along the canal was completed in 2003 and was included as an appendix to the Gowanus Canal RI report submitted to NYSDEC in December 2009. The report includes information about other petroleum sources, asphalt production, and users of coal tar. Appendix C of this report includes selected information from the 2003 study.

1.2.1.4 Gowanus Canal

The Gowanus Canal was constructed between 1853 and 1869 and was designed as a conveyance channel for barges (NYC Department of City Planning, 1985). It has served not just for conveyance of materials and supplies via barge, but also for sewage and industrial wastes. The City of Brooklyn constructed sewers emptying into the Canal as early as 1858 (Hunter Research, Inc., et al., 2004).

The confined nature of the Canal and limited tidal exchange has resulted in sedimentation and water quality issues since construction (Hunter Research, Inc., et al., 2004). By 1889, numerous efforts had been made to improve flow-through and flushing of stagnant water from the Canal, as follow:

- The City of Brooklyn constructed storm sewer outfalls that drained the Fort Greene section of Brooklyn at the top of the Canal in 1899 and the Degraw Street sewer in 1904, in an attempt to flush the stagnant waters of the Canal (Hunter Research, Inc., et al., 2004).
- In 1911, the Gowanus Canal Flushing Tunnel was constructed by the Borough of Brooklyn (Brooklyn New York Annual Report, 1906). The tunnel was designed to pull less polluted waters from Gowanus Bay into the Gowanus Canal at approximately 325 million gallons of water per day (MGD). The actual operating daily volume was about 160 MGP (New York Department of Environmental Protection [NYCDEP], 2008). During its first continuous run, the flushing tunnel exchanged the water volume of the canal every eight hours (Engineering Record, 1911). Mechanical failure rendered the pump inoperable in the early 1960s (Hunter Research, Inc. 2004).
- It is probable that the Flushing Tunnel induced movement of water for the 49 years it operated, transporting NAPLs and polycyclic aromatic hydrocarbons (PAHs) from downstream locations; some of the NAPLs and PAHs probably settled in sediments adjacent to the Site. Tar spills/discharges to the canal were also probable during the Site period of operation. The flushing tunnel likely had some effect on the ultimate distribution of the tar.
- The City built the Gowanus Canal Pump Station at the head of the Canal in 1908. The Butler Street Force Main connected it to the Bond-Loraine Sewer in 1947 (City of New York, 2008).
- The Owl's Head sewage treatment plant was built in 1952 (City of New York, 2008).
- The United States Army Corps of Engineers (USACE) conducted dredging activities to maintain the shipping channel of the Gowanus Bay to the Gowanus Canal from 1881 through 1954 (GEI, 2003).

The following table summarizes documented dredging events within the canal and closer to the Site.

Applicant	Approval Date	Description
Ira Bushey & Sons	4/29/71	Dredge portion of Henry St. Basin to 35 feet MLW. Removed approximately 20,000 cubic yards (CY).
NYC Economic Development Administration Dept. of Ports and Terminals	11/22/71	Dredge at the foot of 29-32 Ave. to 35 feet MLW. Removed approximately 5,000 CY.
NYC Dept of Water Resources	11/7/74	Dredge 7-foot channel from Douglass to Sackett St. and a 10-foot channel from 2nd Ave. to 9th St. Removed approximately 35,000 CY.
International Terminal Operations	11/21/75	Dredging vicinity of 20-21 St. Pier to 30 feet MLW. Removed approximately 40,000 CY.
Transit Mix Concrete Corp.	4/20/78	Dredge at the foot of Ninth and Huntington Street to 10 feet MLW. Removed approximately 1,800 CY.

- By 1984 the Gowanus Canal contained nine combined sewer overflows (CSOs) and four continuous dry weather sewer discharges. These discharged 16.6 million gallons (MG) of raw sewage and 4 MG of combined sewer overflows, respectively, into the Canal on a daily basis (Stone & Webster Engineering Corporation, 1984).
- Sewage discharge to the Gowanus Canal was reduced but not eliminated after the construction of the Red Hook Treatment Plant in 1987 (Hunter Research, Inc., et al., 2004).
- In 1998, NYC conducted a limited amount of dredging at the flushing tunnel discharge location near Parcel VIII, to prepare for reactivation of the flushing system. The specific extent/footprint of the dredging is unknown.
- In 1999, the Gowanus Canal Flushing Tunnel was reactivated. It pumped approximately 160 MG per day (NYSDEC, 2008) of water from Buttermilk Channel on the East River, down the Gowanus Canal, from the head of the Canal toward Gowanus Bay, until 2010. The Flushing Tunnel was shut down again in 2010 for modifications and New York City anticipates restarting the Flushing Tunnel in 2014.
- In 2001, the Gowanus sewage pump station was upgraded to new pumps having a capacity of 28.5 MGD. CSO flows exceeding the capacity of the pump station are discharged to the Canal at CSO RH-034 (Figure 7).

1.2.1.5 Post-MGP Operation Land Use

Between 1938 and 1948, BUG sold the former MGP parcels, which were sub-divided and redeveloped for commercial, industrial, and recreational uses. A summary of property transfer information is provided below:

Summary of Fulton MGP Property Transfer Information	
Parcel I	BUG sold Block 425, Lot 1 to Belroe Realty Corporation on March 15, 1943.(Stuart Title Insurance Company, January 2006)
Parcel II	BUG sold Block 419, Lot 1 to City of New York on April 27, 1938. (Stuart Title Insurance Company, May 2006)
Parcel III	BUG sold Block 426, Lot 1 to 61 Navy Street Realty Corporation on November 30, 1945.(Stuart Title Insurance Company, February, 2006)
Parcel IV and portion of Parcel III	BUG sold Block 428, Lot 17 to Ebla Realty Corp. on December 17, 1945. (Stuart Title Insurance Company and First American Title Insurance Company 2005, November 2005)
Parcel V	BUG sold Block 420, Lot 1 to News Syndicate Co., Inc. on December 21, 1934. (Stuart Title Insurance Company, May 2006)

These parcels are all currently owned and/or used by third parties that are unrelated to National Grid. A brief history of the post-MGP land-use was developed from available Sanborn maps, aerial photographs and land records. Table 1 presents a summary of environmental records for each parcel.

- Parcel I: BUG sold the property in 1943. The current warehouse building was constructed by 1950, based on the 1950 Sanborn map. The warehouse was indicated as vacant; however, a gasoline tank is depicted beneath the building on the 1950 Sanborn map. By 1969, the building was occupied by T.E. Conklin Brass & Copper Company. Two gasoline tanks were depicted in the current parking lot area on the southwestern side of the building. The warehouse was occupied by the T.E. Conklin Brass Company for warehousing from at least 1969 until circa 2007 according to Sanborn map information (Appendix C). From at least 2007, the warehouse was used by Admiral Metals for metal storage, and it was also used for office furniture storage and for storage of property owned by the Brooklyn Museum. In 2010, the current property tenant began renovation of the warehouse into a movie studio.
- Parcel II: The City of New York acquired the property in 1938 and ultimately developed the property for recreational use. The property is currently known as the Thomas Green Playground and is managed by the New York City Department of Parks and Recreation. In a 1943 aerial photograph, handball courts are present on the western portion of the Parcel. A Comfort Station is shown on the northern portion of the Parcel in the 1950 and 1969 Sanborn maps. The current pool area was constructed by 1972. The swimming pool and smaller wading pool, changing rooms, and pool filter room are shown in a 1975 aerial photograph and on the 1977 Sanborn Map. The Thomas Greene Playground currently includes two areas: the playground

area and swimming pool/handball court area. The handball court and pool areas encompass the western portion of the parcel. The eastern portion of the parcel is the playground area that includes asphalt paved playing courts, benches, and tree plantings that are planted in tree wells.

- Parcel III: BUG sold the majority of the property on November 30, 1945 and the remainder on December 17, 1945. A warehouse/industrial building was constructed by 1950 and was occupied by the Majestic Metal Spinning & Stamping Company, Inc. from at least 1950 until 1982 (1950 to 1982 Sanborn maps). Sanborn Maps show that the Majestic Metal Spinning & Company operations consisted of plating and spraying operations. The southern portion of the current warehouse building was built in 1955 and operated as a warehouse until 1982. According to the 1986 Sanborn map, Adams Book Company, the current business, occupied the warehouse. The eastern portion of the warehouse was used for automobile repair from circa 1985 to 2007 according to Sanborn Map information and 1985 and 1996 city directory information (Cole Publications 1985 and 1996). The exterior portion of the Parcel has remained undeveloped. It is currently used as a parking lot for the Adams Book Company.
- Parcel IV: BUG sold the property on December 17, 1945. It was utilized for truck parking, truck wrecking, and truck sales from 1950 through 1995, based upon Sanborn map information. The property is currently used for roll-off bin storage, truck maintenance, and storage of construction equipment and supplies.
- Parcel V: BUG sold the property to News Syndicate Co., Inc. on December 21, 1934. The 1951 Sanborn Map shows the property was developed as a garage. The garage had a paint shop and two gasoline storage tanks. The News Syndicate Co., Inc. operated the garage from 1951 through 1995 according to Sanborn maps. By the 2001 Sanborn map, the Ryder Truck Rental – Brooklyn Garage occupied the warehouse. Ryder Truck Rental appears to occupy the Site based upon the 2001 through 2007 Sanborn maps. After 2007, the on-site building on the Parcel was developed for use as a warehouse. Currently, the building is used for a rock climbing gym (Brooklyn Boulders, LLC) and a warehouse (Royal Items, Inc./Accessory Delux, Inc. [Royal Items].

A summary of current ownership and use information is provided in the table below.

Former Fulton MGP Site Parcels				
Parcel ID	**Property Information**	**Former Gas Plant Use**	**Current Use**	**Property Ownership**
Parcel I	270 Nevins Street [Block 425 Lot 1] ±1.19 acres	Oil/naphtha tank, oil room, tar and oil tanks, generator/retort house, condenser house, coal shed	Commercial Use: Former Warehouse [Being renovated into movie production studio] constructed circa 1950	270 Nevins St. Properties, LLC
Former Fulton MGP Site Parcels				
Parcel ID	**Property Information**	**Former Gas Plant Use**	**Current Use**	**Property Ownership**
Parcel II	225 Nevins Street [Block 419 Lot 1] ±2.53 acres	Hydrogen tank (gas holder), purge tank, (2) fuel oil tanks, (6) underground gas oil tank, (9) unidentified tanks, 500,000 gallon, pipe lay down yard	Thomas Greene Playground-elevated above existing street grade; may have been filled and tiered to construct the park	City of New York [Department of Parks and Recreation]
Parcel III	537 Sackett Street [Block 426 Lot 1] ±0.92 acre	Purifying houses, scrubbers, gas holder, a portion of a second gas holder, governor house	Commercial Use: Warehouse	ATS Realty, Inc.
	[Portion of Block 426 Lot 17] ±0.06	Coal and oxide shavings storage	Unpaved Parking lot	242 Nevins, Inc.
Parcel IV	560 Degraw Street [Block 426 Lot 17] ±0.88 acre	Gas holder and coal shed	Commercial Use: [Roll-off bin storage/truck maintenance/construction equipment and materials storage]	242 Nevins, Inc.
Parcel V	191 3rd Avenue (aka 575 Degraw Street [Block 420, Lot 1] ±0.91	Gas holder, engine room, water tank and four "driven wells"	Commercial Use: Warehouse and Rock Climbing Gym	JAEZ Realty, LLC

Sources:
1. New York City Oasis Map http://www.oasisnyc.net/map.aspx
2. New York City Department of Finance Digital Tax Map Online http://gis.nyc.gov/dof/dtm/index.jsf

1.2.2 Surrounding Property Use

GEI also conducted RI investigations at three surrounding, off-site properties, described in the table below.

Off-Site Parcel Summary			
Parcel ID	**Property Information**	**Current Property Use**	**Property Ownership**
Parcel VI	242 Nevins Street [Block 418 Lot 1]	Commercial Use: Office and Truck Repair Garage and Vehicle/Equipment Storage	242 Nevins, Inc.
Parcel VII	226 Nevins Street (aka 234 Butler Street) [Block 411 Lot 24]	Commercial Use: Truck Repair Garage Vehicle/Equipment Storage	226 Nevins Corp.
Parcel VIII	479 Degraw Street (aka 210 Douglass Street) [Block 417 Lot 21]	Commercial Use: Paved Parking lot	Magnifico Enterprises, Inc.

Sources:
1. New York City Oasis Map http://www.oasisnyc.net/map.aspx
2. New York City Department of Finance Digital Tax Map Online http://gis.nyc.gov/dof/dtm/index.jsf

Surrounding property use adjacent to the Fulton former MGP include:

- North: Degraw and Douglass Street ROWs are located to the north. To the north of Degraw Street is the off-site property of Parcel VI. A mix of commercial businesses is located to the north of Douglass Street ROW including a truck garage for Petroleum Tank Cleaners, parking area, and carpentry shops. Parcel VII is located to the north of Douglass Street.
- East: Commercial businesses including construction lay down area, used car lot, and 3rd Avenue are located adjacent to the Site. A gym and commercial warehouse building are adjacent to the former holder at191 3rd Avenue.
- South: Sackett and Degraw Street ROWs are located to the south of the former Fulton MGP. Commercial businesses include an auto repair shop, auto collision, parking lots, and second story residential apartments and residential dwellings are located to the south of Sackett Street. Parking and commercial warehouse uses are present along Degraw Street to the north of 3rd Avenue.
- West: Gowanus Canal and Parcel VI. To the west of the Gowanus Canal, commercial businesses include former Bayside Fuel Property to the south of Sackett Street and a fuel truck parking area and equipment staging area to the north of Sackett Street. Parcel VIII is located to the west of the Gowanus Canal.

1.3 Physical and Environmental Setting

The Site is located within a heavily industrialized and developed area primarily covered with buildings and pavement. The topography and surface water drainage features for the RI study area are shown in Figure 7. Topography in the study area slopes from a high elevation of 21 ft North American Vertical Datum 1988 (NAVD88) near Parcel V to the lowest elevations bordering the Gowanus Canal (approx. 5 ft NAVD88).

Stormwater run-off generally drains westward on the eastern side of the RI study area to the Gowanus Canal and drains eastward to the Gowanus on the western portion of the RI study area. Stormwater run-off in the street ROWs collects in catch basins and is conveyed via sewer pipes to the Gowanus Canal.

A localized stormwater collection system is present in the area of the basketball courts on Parcel II and is also present on Parcel VI. According to Envirotrac (2006), the stormwater collection system on Parcel VI includes two concrete catch basins located in the central portion of the parking lot area of that parcel. The catch basins drain to an on-site oil water separator that is located beneath the on-site building. The flow of the drainage structures and oil water separator are unknown (Envirotrac, 2006).

The Gowanus Canal is a tidal water body that experiences semi-diurnal tides (i.e., two high and two low tides) a day. The tidal range in the Canal ranges from 4.7 to 5.7 feet (HDR Engineering, Inc. [HDR], et. al, 2011).

Surface water flow in the Gowanus Canal is comprised of CSOs and stormwater discharges, tidal exchange of seawater from Gowanus Bay and the artificial influx of water from the Flushing Tunnel. The urbanization of the Canal watershed and construction of the CSO and stormwater systems has eliminated freshwater sources other than CSOs and stormwater discharges (USACE, 2003).

Four large CSOs (RH-033, RH-034, RH-037 and RH-038) and one stormwater outfall (RH-615) are located to the north of the Union Street Bridge (Figure 7). During wet weather, the combined sewer system becomes overwhelmed, and a mixture of sewage and stormwater is discharged into the Canal. The current estimated annual discharge of the CSOs is approximately 122.6 million gallons annually to the north of Union Street Bridge (NYCDEP, 2008).

The Gowanus Canal flushing Tunnel was shut down in 2010 for modifications and is not expected to operate again until 2014. The NYCDEP is operating an interim canal oxygen transfer system intended to maintain oxygen levels in the Canal. NYCDEP (2008) projects that the Flushing Tunnel will pump approximately 215 MGD of water from the Buttermilk Channel to the head of the Canal at Douglass Street when it is back in service.

The Canal is classified by NYSDEC as class SD surface water, which is suitable for fish survival, but not fish reproduction, and is not suitable for primary or secondary human contact (i.e., swimming and boating, respectively). Consumption of fish is not allowed.

1.3.1 Regional Geology

Beneath the RI study area, the following geologic materials are present in stratigraphic order (from deepest to shallowest):

- Fordham Gneiss
- The Jameco Gravel
- Glacial outwash sands with discontinuous silt and till lenses
- Alluvial/Marsh deposits
- Fill

Figure 8 presents a conceptual stratigraphic profile of these materials.

A detailed discussion of the site-specific geology and hydrogeologic findings is presented in Section 3 of this report. The sections below discuss the regional geology and hydrogeology so that the reader can gain an understanding of how the Site fits into the regional geologic framework. The following discussion of regional geology is presented in stratigraphic order, that is, from the deepest geologic unit to the shallowest.

Bedrock encountered beneath the Site is the Fordham Gneiss, which is described as a metamorphosed, medium- to coarse-grained igneous rock unit of Precambrian Age (Brock and Brock, 2001) (Figure 8). Regional down-warping of bedrock beneath the Site and the vicinity has resulted in a southeast-dipping bedrock surface of approximately 80 feet per mile (USEPA, 1983 and Cartwright, 2002). Bedrock elevations within the vicinity of the Site range between -99 to -199 feet NAVD88 (Buxton, Soren, Posner, and Shernoff, 1981). At the Site, bedrock was observed in one soil boring, GCMW-30D2, which is located at Parcel I adjacent to Gowanus Canal. Weathered bedrock was observed at a depth of 151 feet below ground surface (bgs) [elevation -142 feet] and bedrock was observed at a depth of 159 feet bgs [elevation -150 feet].

Within Kings County, bedrock is generally overlain unconformably by unconsolidated late Cretaceous age deltaic deposits (Clay Member of the Raritan Formation), overlain by Pleistocene age channel fill (Jameco Gravel) and lagoonal marine deposits (Gardiners Clay), overlain by Upper Pleistocene (Wisconsin) age glacial deposits and Holocene age marsh/alluvial deposits and artificial filling (Cartwright, 2002). In the vicinity of the former Fulton MGP, Jameco Gravel and glacial deposits lie unconformably upon bedrock; the Clay Member of the Raritan Formation and the Gardiners Clay were not encountered.

The Jameco Gravel is described as a channel fill deposit associated with the ancestral Hudson River channel scour of southern Kings and Queens Counties (Cartwright, 2002). The unit consists of dark coarse sand and gravel with cobbles and boulders and ranges in thickness from absent at some locations to approximately 200 feet thick in Queens County (Cartwright, 2002). The approximate elevation of the surface of the Jameco Gravel ranges between -100 and -150 feet (NAVD88) beneath the Site and vicinity and slopes toward the southeast (Buxton, Soren, Posner, and Shernoff, 1981).

The Upper Pleistocene glacial deposits overlie the Jameco Gravel and Cretaceous age deposits near the Site. Glacial deposits in the vicinity of the Site consist of terminal moraine and ground moraine deposits, which consist of poorly sorted mixtures of clay, silt, sand, gravel, and boulders, and glacio-fluvial outwash deposits consisting of moderately to well-sorted sands and gravels and typically range in thickness between 100 and 200 feet (Cartwright, 2002).

Holocene age marsh deposits consist of sand, silt, organic material along stream channels and marshes, and have a maximum thickness of 50 feet within limited areas of Kings and Queens County (Busciolano, 2002).

Fill is defined as soil or rock used to raise the surface of the ground (New York State Geological Survey, 2011)

1.3.2 Regional Hydrogeology

Four regional groundwater aquifers are present in the Long Island area, in order of increasing depth.

- The Upper Glacial Aquifer consisting of Upper Pleistocene glacial deposits. Localized Holocene marsh and alluvial deposits (including clayey and silty deposits) and fill are also grouped in the Upper Glacial Aquifer. These materials are typically less permeable than the underlying aquifers and may create locally confined conditions (Busciolano, 2002).
- The Jameco Aquifer consisting of the Jameco gravel
- The Magothy Aquifer consisting of the Late Cretaceous Magothy Formation and Matawan Group deltaic deposits
- The Lloyd Aquifer consisting of the Lloyd Sand Member

However, the Lloyd Aquifer and the Magothy Aquifer do not extend westward to the Site vicinity (Busciolano, Monti, and Chu, 1997 and Busciolano, 2002); consequently, the discussion will focus on the Upper Glacial Aquifer, the Jameco Aquifer, and the confining units that bound them.

The Upper Glacial Aquifer is generally unconfined (water table); however, it can be locally confined by the presence of silt and clay layers within moraine deposits. Groundwater within the Upper Glacial Aquifer flows west to southwest towards Upper New York Harbor. The horizontal hydraulic conductivity of glacial outwash deposits of the Upper Glacial Aquifer on Long Island were calculated at 270 feet per day (9.5×10^{-2} centimeters per second [cm/s]) (Franke and Cohen, 1972 in Cartwright, 2002). The horizontal hydraulic conductivity for the poorly-sorted moraine deposits is likely in the range of 135 feet per day (4.4×10^{-2} cm/s) (Buxton and Shernoff, 1995 in Cartwright, 2002).

The Gardiners Clay underlies the Upper Glacial Aquifer and acts as a hydrologic confining unit where it is present (Cartwright, 2002). The Gardiners Clay was not encountered during RI activities at and adjacent to the former Fulton MGP.

The Jameco Aquifer is confined by the overlying Gardiners Clay (where present) and has horizontal hydraulic conductivities that range from 200 to 300 feet per day (7.1×10^{-2} to 1.1×10^{-1} cm/s) (Busciolano, 2002). An un-named clay member of the Raritan Formation and Precambrian bedrock form the lower confining unit of the Jameco Aquifer (Busciolano, 2002).

1.3.3 Regional Water Use

The public water supply is currently provided to the Site and surrounding area by the NYC Water Supply System. The water supply comes from a series of aqueducts from interconnected watershed areas, the Catskill/Delaware Watersheds and Croton Watershed, located 50 to 125 miles north of New York City. According to Cartwright (2002), the use of groundwater for public supply in Kings County was discontinued in 1947.

An environmental database search for available federal and state well data within the vicinity of the RI study area was performed by Environmental Data Resources, Inc. (EDR). The EDR report confirmed that there are no public water supply wells in Kings County within a 1-mile radius of the former Fulton MGP.

1.3.4 Local Water Use

The EDR report provided search results for wells listed in the United States Geological Survey (USGS) National Water Inventory System. These are locations that the USGS collects or has collected water level data. According to EDR, there are no USGS wells at the former Fulton MGP or within the RI study area. Fifty-nine USGS wells were located approximately within a 1-mile radius of the former Fulton MGP.

GEI submitted a Freedom of Information Act (FOIA) letter to NYSDEC Region 1 for water well records and well information near the Site. Information for a number of wells was received as follows:

- Five wells were formerly located in the northern portion of Parcel II adjacent to 3rd Avenue between Degraw and Douglass Streets. These five wells were abandoned in the early 1920s.
- Three wells were installed in 1907 by the Knickerbocker Ice Company located at the intersection of Bond and Douglass Street to the west of the Fulton MGP footprint. These wells were used to operate condensers first by the Knickerbocker Ice Company and then (circa 1949) by the American Ice Company. Abandonment is uncertain; however, the ice companies are no longer located at this address.
- A 1936 well record indicated a well located at 223 Nevins Street to the north of the Fulton MGP. The record indicates that the well was used for cooling. No decommission date was listed, but that address is currently a vacant lot.
- A 1936 well record indicated a well located at 302 Butler Street to the north of the Fulton MGP. The record indicates that the well was sealed and abandoned prior to 1930.
- A well record indicated a well located at 188 Third Avenue to the north of the Fulton MGP. The owner was the Manifold Supplies Company. The record indicates that the well was used for cooling water. The Manifold Supplies Company sold this property in 1968. No records were encountered regarding abandonment of the well.

The FOIA request and NYSDEC response letters are provided in Appendix D.

1.4 Environmental Records, Fulton MGP Parcels

GEI submitted FOIA request letters to NYSDEC Region 2 to obtain environmental records for the former Site properties. Records were also requested for adjacent and upgradient properties undergoing environmental investigation and remediation. Information from the FOIA request is provided in Appendix D and information pertaining to potential non-MGP impacts is summarized below. Figure 9 presents a summary of the environmental records search information.

1.4.1 Fulton MGP Parcels

The table below summarizes the source of the environmental records obtained for the former Fulton MGP parcels.

Property Address	Location	NYSDEC Environmental Record Information
Fulton Municipal Works MGP Footprint		
270 Nevins Street	Parcel I	PBS No. 2-349216 and 2-483001
225 Nevins Street	Parcel II	No information provided
537 Sackett Street	Parcel III	Spill Report No. 9310522 PBS No. 2-605467
560 Degraw Street	Parcel IV	No information provided
191 Nevins Street (aka 280 Douglass Street)	Parcel V	PBS No2-333352 and Spill Report Nos. 9310083, 9112095 and 9415530/9415539

1.4.1.1 Parcel I

Petroleum Bulk Storage (PBS) record No. 2-349216 documents three underground storage tanks (USTs) that held gasoline and diesel fuel. No installation date is provided. However, the record indicates the tanks were closed in place on April 1, 1993.

PBS record No. 2-483001 indicates that two tanks were used to store #2 fuel oil at the property. A 5,000-gallon steel UST was closed and removed on August 1, 1998. A 5,000-gallon fuel oil aboveground storage tank (AST) was installed inside the building in 1998. That tank was closed and removed on October 15, 2010.

1.4.1.2 Parcel III

Spill report (No. 9310522) dated September 20, 1993, indicates that 5 gallons of #2 fuel oil were spilled on the sidewalk. The spill was closed on September 30, 2011. The PBS record (No. 2-605467) indicates that one 7,000-gallon steel UST was used at the Parcel to store #2 fuel oil. The UST was tested on April 27, 2001, and was closed in place on May 1, 2001. The record indicates that a 1,500-gallon steel AST in concrete used for #2 fuel oil storage was installed on January 1, 1983, and is still in operation.

1.4.1.3 Parcel V

PBS record 2-333352 indicates that there were six USTs used at the Parcel:

- Four 4,000-gallon steel USTs were used to store diesel.
- One 4,000-gallon steel UST was used to store gasoline.
- One 5,000-gallon steel UST was used for to store #2 fuel oil.

The five 4,000-gallon USTs were installed in 1984 and were closed in place April 1, 1998. The 5,000 UST was installed in 1939 and was closed in place on December 1, 1995.
Four spill records were reviewed:

- Spill Report 9112095- release of 30 gallons of fuel oil to the pavement and approximately one gallon to the sewer on February 25, 1992. The spill was closed on March 3, 1992.
- Spill Report 9310083 - release of 15 gallons of fuel oil to the pavement on November 18, 1993. The spill was closed on November 18, 1993.
- Spill Reports 9415530/9415539 - release of 40 gallons of fuel oil onto the roof of the building through a vent pipe on February 28, 1995. The spill was closed on March 1, 1995.

Stained soils, sheens, and strong petroleum odors were observed in the FW-MW-14 soil boring and monitoring well located in the Douglass Street ROW at Parcel V, which are discussed below in section 4.

1.4.2 Off-Site Parcels

The table below summarizes the source of the environmental records obtained for off-site properties.

Adjacent Off-Site Properties		
242 Nevins Street	Parcel VI	Spill Report No. 0510846
267 Douglass Street	Northeast of Parcel II (Thomas Greene Playground Area)	Spill Report No. 8800904 PBS No. 2-070114
225 3rd Avenue		Spill Report No. 0612588 and 0204259
510 Sackett Street (Former Bay Side Fuel Oil Terminal)	East of Parcel I (Western side of Gowanus Canal)	Spill Report No. 9810785 and eight closed spill reports.
553 Sackett Street Block	South of Parcel III and IV	No information provided
560 Sackett Street	Southeast of Parcel IV (Intersection of Sackett and 3rd Avenue)	Spill Report No. 9412033 PBS No. 2-604492
239 Nevins Street	Northeast of Parcel II (Thomas Greene Playground Pool Area)	No information provided
Nearby and/or Upgradient Off-Site Properties		
169 3rd Avenue (Citgo Service Station)	Northeast of Parcel II and Parcel V	Spill Report No. 9506588
239 Nevins Street	Northeast of Parcel II (Thomas Greene Playground Pool Area)	No information provided
Nearby and/or Upgradient Off-Site Properties		
223 Nevins Street	Northeast of Parcel II (Thomas Greene Playground Pool Area-north of Butler Street)	Spill Report Nos. 0613824 and 0712570 PBS No. 2-611037
318 Nevins Street (Verizon Property)	Southwest of Parcel I (south of Union Street)	Spill Nos. 9207367, 9314103, 0306012, 9208840, and 9801467
204 4th Avenue (Hess Service Station)	East of Parcel V	Spill Report No. 9713442 PBS No. 2-337722
164 4th Avenue (BP Service Station)	Southeast of Parcel V	Spill Report No. 9713442 PBS No. 2-337722

1.4.2.1 Parcel VI

Spill report (No. 0510846) indicates that 200 gallons of #2 fuel oil was spilled on December 16, 2005. The spill spread across ponded water in the parking lot and extended approximately 250 feet westward from the entrance gate at Nevins Street to the bulkhead area.

Petroleum Tank Cleaners was retained by the property owner to remediate the spill. Approximately 2,000 gallons of non-hazardous water, 15 cubic yards of oily debris, and 30 tons of non-hazardous soil were removed and disposed of at an off-site disposal facility.

A shallow subsurface investigation was completed on March 16, 2006. The scope of work included the installation of twelve shallow soil borings using a hand auger. One surface soil sample was analyzed for VOCs and SVOCs. One compound, phenanthrene, was detected at 148 milligrams per kilograms (mg/kg), which was below the applicable NYSDEC standards. The spill report was closed on April 21, 2006.

1.4.2.2 267 Douglass Street

Spill report No. 8800904 was issued on April 28, 1988, for a tank test failure of a 7,000-gallon UST located beneath the sidewalk. PBS record No. 2-070114 indicates that the tank was used to store #2 fuel oil and was closed in place on April 1, 1998. The property is located upgradient and adjacent to Parcel I.

1.4.2.3 510 Sackett Street (Former Bayside Fuel Oil Depot)

The Bayside Fuel Oil Depot Corporation property at 510 Sackett Street was a former Major Oil Storage Facility (MOSF) that used a 1,500,000-gallon compartmented tank to distribute fuel to supply trucks.

The 1,500,000-gallon compartmented tank contained five smaller tanks:

Size (gallons)	Material Stored
100,000	#2 fuel oil
200,000	kerosene
300,000	diesel fuel
400,000	#2 fuel oil
500,000	#2 fuel oil

Nine NYSDEC spill numbers are associated with the address between 1991 and 2010. All of the spill numbers are closed with the exception of Spill No. 0902825, which was opened subsequent to the findings of a Site Assessment Report by AKRF Environmental Planning Consultants, dated July 30, 2009.

AKRF, Inc. performed the site assessment to evaluate the environmental conditions of soil and groundwater at the property. Based on the findings in the site assessment report, NYSDEC concluded that significant contamination was present and required the development of a remedial action plan (RAP) due on October 14, 2009. Additional documents were not available to GEI at the time of the preparation of this RI report.

GEI encountered stained to oil-saturated soils with moderate petroleum odors in soil borings FW-SB-49 and GC-GP-07, which are located in the Sackett Street ROW adjacent to the property. USEPA encountered hydrocarbon sheens in soil boring GC-MW03 adjacent to the Gowanus Canal.

1.4.2.4 318 Nevins Street [Verizon Property]

318 Nevins Street is used by Verizon as a fleet service center for repair trucks. The service center previously used fuel dispenser pumps and four petroleum USTs for the fleet. NYSDEC issued five spill report numbers for the property. All of the spill reports were closed with the exception of Spill No. 9207367, which was issued for the observation of gasoline in a monitoring well on September 24, 1992.

A number of remedial activities were completed in association with spill report 9207367, NYSDEC-approved RAP and Operations, Maintenance and Monitoring Plan documents:

- Removal of the four petroleum USTs
- Excavation of approximately 800 tons of petroleum contaminated soils and 838 gallons of impacted water
- Injection of over 2,900 pounds of oxygen releasing compound (ORC)
- Completion of over 8 years of groundwater monitoring

Significant concentrations of benzene, toluene, ethyl benzene, and xylene (BTEX) and methyl-tert-butyl-ether (MTBE) have persisted in monitoring well MW-8, on the southwestern side of Union Street and MW-11, on the northeastern side of Union Street.

Groundwater flow is to the northeast toward the southern extent of the RI study area. Soils with staining, sheens, and petroleum odors were observed at the apparent water table in FW-SB-37 (Figure 3). BTEX and MTBE were detected in FW-MW-18 during the September 19, 2009 groundwater sampling event.

On July 12, 2011, Vadim Brevbo (NYSDEC) confirmed that no additional RAPs or investigation reports have been produced in association with this spill number since August 2009, and that quarterly monitoring continued.

1.5 Previous Investigations

1.5.1 NYSDEC Site Characterization-September 2007

The NYSDEC conducted a Site Characterization of the Fulton former MGP in 2007. The findings were presented in the September 2007 report: *Site Characterization Report, Fulton Former Manufactured Gas Plant, Brooklyn, Kings County, New York, Site No. 2-24-051*.

The SC included the installation of 29 soil borings (KSF-SB-1 through KSF-SB-29) and seven monitoring wells (MW-1 through MW-7) within Thomas Greene Playground and public street ROWs and sidewalks of Degraw, Sackett and Nevins Streets. The NYSDEC SC locations are shown in Figure 3. The SC boring logs are provided in Appendix E.

The NYSDEC collected thirteen soil samples for VOC and SVOC analysis. Groundwater analytical samples were collected from the seven monitoring wells. Concentrations of VOCs and SVOCs exceeded the established soil standards and New York State Ambient Water Quality Standards, Criteria and Guidance Values (NYSAWQSs). The physical findings from the NYSDEC SC are summarized in this RI Report.

Based on the findings of the SC investigation, the NYSDEC recommended that a RI/ Feasibility Study (FS) be completed to determine the full nature and extent of contamination at the Fulton former MGP.

1.5.2 Gowanus Canal Investigations

1.5.2.1 KeySpan Gowanus Canal Investigation 2009

On behalf of KeySpan (National Grid), GEI conducted an investigation to assess the environmental conditions within the Gowanus Canal. National Grid undertook this work in response to a NYSDEC AOC (Index # A2-0523-0705) [Settlement Agreement]. The investigation was initiated relative to a separate site. However, some data were gathered adjacent to the Fulton Site during the Canal investigation, as follows:

- Sediment cores GC-SED-01, CG-SED-02, and GC-SED-03 were collected adjacent to Parcel VII.
- Sediment cores GC-SED-04 and GC-SED-05 were collected adjacent to Parcel VI.
- GC-SED-07, GC-SED-08, and GC-SED-09B were collected between Parcels VI and I.
- Soil boring GC-GP-05 was advanced on the western side of the canal in Degraw Street.
- Soil boring GC-GP-06 was advanced between Parcels VI and I in Degraw Street.
- Soil boring CG-GP-07 was advanced on the western side of the canal across from Parcel I in Sackett Street.

Sediment and ground surface elevations were recorded at each of these locations, to support evaluation of potential migration from the landside into the canal (Section 4).

The investigation was also performed to evaluate potential impacts to the Gowanus Canal from the numerous former industries that lined the Canal as well as current and former urban discharges to the Canal. As a result, GEI evaluated sediment, surface water, and outfall discharges and sediment along the entire length of the Canal. GEI also reviewed and interpreted biological data collected on behalf of the USACE.

The findings of the Gowanus Canal Investigation are provided in the following NYSDEC-approved reports:

- Gowanus Canal Investigation Executive Summary Report, AOC Index No. A2-0523-0705, GEI Consultants, Inc., December 2009.
- Remedial Investigation Technical Report, Gowanus Canal, Brooklyn, New York, AOC Index No. A2-0523-0705, GEI Consultants, Inc., December 2009.
- Gowanus Canal Ecological Investigation Report, Gowanus Canal, Brooklyn, New York, GEI Consultants, Inc. December 2009.
- Environmental Forensic Investigation Report, Gowanus Canal, Brooklyn, New York, NewFields Environmental Forensics Practice, LLC, March 2007.

GEI's investigation revealed the following:

- The upper 3 feet are dominated by fine-grained organic-rich accumulations of sewage and CSO outfall materials. These materials are impacted by the presence of multiple chemical stressors (pesticides, polychlorinated biphenyls (PCBs), metals, PAHs, and BTEX.

- Isotopic age dating of the sediments established that the upper 3 feet of sediments were deposited beginning in the 1960s, well after the Fulton MGP Site ceased operation.
- Physical observations and environmental forensic analyses indicate that the hydrocarbons (including PAHs) in the upper 3 feet of sediments are largely derived from petroleum sources.
- Gowanus Canal shallow sediment and surface water quality is adversely impacted by multiple chemical and physical stressors largely unrelated the former MGPs.
- Canal sediments were toxic to sediment dwelling organisms in controlled laboratory exposures, with sewage-related contaminants, including ammonia, being the drivers of the toxicity.
- Ecotoxicological analyses indicated the current canal benthic invertebrate communities are inherently impoverished due to the chemical and physical stressors related to CSO discharges and other sources. As a result, the benthic communities consist of organic pollution tolerant organisms, the distribution of which seems to be driven by physical habitat variability.
- Tar was primarily encountered below the accumulated sewage/sediment in the native coarse-grained sediment materials.
- The shallowest tar observed in a land based soil boring for the Gowanus Canal study was encountered in soil boring GC-GP-06, in Degraw Street near the canal. Concentrations of BTEX, PAHs, pesticides, and metals were detected above applicable New York State Standards. A summary of the detections is provided in Table 2.

Soil boring logs and sediment core logs are located in Appendix E. The physical findings and analytical data from landside borings are summarized below in Section 4 of this RI Report.

1.5.2.2 USEPA Gowanus Canal Investigation 2011

On March 10, 2010, the USEPA added the Gowanus Canal to the Superfund National Priorities List (NPL). National Grid entered into an AOC (CERCLA-02-2010-2009) with USEPA for the Canal on April 29, 2010. The City of New York also entered into an AOC (CERCLA-02-2010-2011) for the Gowanus Canal Site with USEPA.
The findings of the USEPA Gowanus Canal RI are provided in the January 2011 *Draft Gowanus Canal Remedial Investigation Report, Volume I prepared by HDR, et al. dated January 2011*.

USEPA collected sediment cores in the Gowanus Canal, as follows:

- ERT 1-1, ERT 1-2, ERT 1-3, GC-SD107, GC-SED124, GC-SD125, and CG-SED126 were collected adjacent to Parcel VII.
- ERT 2-1, ERT 2-2, ERT 2-3 were collected adjacent to Parcel VI.
- GC-SD152 was collected between Parcels VI and I.
- GC-SD108, ERT 3-1, ERT 3-2, and ERT 3-3 were collected adjacent to Parcel I.

Elevations were not determined for the ERT cores. Therefore, we cannot directly compare elevations of physical impacts with other cores or landside borings.

The USEPA Gowanus Canal RI concluded:

- The top 6 inches of surface sediments contained PAHs, PCBs, and metal compounds (barium, cadmium, chromium, copper, lead, mercury, nickel and silver).
- Deeper accumulated sediments included elevated concentrations of BTEX, SVOCs, pesticides, PCBs and metals.
- NAPL is primarily encountered in native sediments. USEPA suggested the NAPL appears to be associated with tar. However, the USEPA did not conduct chemical forensic analyses to determine the origin of the observed NAPL; their physical descriptions broadly characterized NAPL as "hydrocarbon-like.
- The NAPL contained high concentrations BTEX and PAHs. The report did not reference other potential sources of NAPL (e.g. bulk petroleum storage) along the Canal.
- Primary sources of contamination to the Gowanus Canal include:
  - Direct discharges from historical industrial activities (including CSOs)
  - On-going CSO and stormwater discharges
  - Non-SCO Outfall discharges
  - Discharges from contaminated sites

To the extent they are related, the findings from the hydrogeologic investigation and ambient air sampling have been incorporated into this RI Report. Detected subsurface soils and groundwater analytical results are summarized in Tables 3 and Table 4, respectively. Concentrations of compounds exceeded applicable NYS regulatory criteria as discussed below in Section 4. Background outdoor air sampling results are provided in Table 5. Soil boring logs and sediment core logs are located in Appendix E.

2. Remedial Investigation Methods

This section describes the methods and procedures used during the RI. Unless otherwise noted, the RI was implemented in accordance with the Final RIWP, RI Addendum Work Plans, and a modification to the RI Addendum No. 2 Work Plan that were approved by NYSDEC. Copies of the NYSDEC approval letters are provided in Appendix A. RI investigations completed within Thomas Greene Playground were completed under NYC DPR *Permit To Perform Work On Park Property Permit No. B-12-09NF* dated May 9, 2008.

GEI oversaw the implementation of Fulton MGP RI field activities between May 2008 and May 2011. The RI fieldwork included the following activities:

- Surface soil sample collection
- Subsurface utility location and mark-out
- Test pit excavation and subsurface soil sample collection
- Soil borings installation and subsurface soil sample collection
- Monitoring well installation and development
- Temporary groundwater sampling point installation
- Groundwater sample collection
- Groundwater gauging and gauging for the presence of NAPL
- Hydraulic conductivity testing
- Soil vapor point installation and sample collection
- Indoor and outdoor ambient air sample collection
- Survey of sample locations

The RI sample locations are shown in Figure 3.

During all ground intrusive activities, an air quality monitoring program was conducted in accordance with the provisions of the site-specific Health and Safety Plan (HASP) developed for the RI and in accordance with the NYSDOH Community Air Monitoring Plan (CAMP) requirements (NYSDEC, 2010).

Detailed field procedures, including quality assurance/quality control (QA/QC) sample practices, are provided in the NYSDEC-approved RI scopes of work.

All samples described below were shipped to and analyzed by TestAmerica Laboratories (TestAmerica). Soil and groundwater samples were shipped TestAmerica in Shelton, Connecticut for analysis, except free cyanide samples collected between May and June 2008. During that period, analysis for free cyanide was only available from non-commercial, university laboratories. Clarkson University laboratory completed the free cyanide analysis of soil samples until August 2008, when the USEPA-approved method was commercialized. After that point, free cyanide samples for the Fulton MGP were analyzed by TestAmerica.

Soil vapor and ambient air samples were submitted to TestAmerica in Knoxville, Tennessee.

2.1 Subsurface Utility and Former Structure Location

The NYC and Long Island One Call Center was notified to mark-out locations of subsurface utilities prior to completing ground intrusive activities. Utility companies and utility company contractors marked out utility lines within the public street ROWs.

Hager-Richter Geoscience, Inc. of Fords, New Jersey, Utility Survey Corporation of New Windsor, New York and Diversified Geophysics, Inc. of New Hyde Park, New York were contracted by GEI to identify and mark subsurface utilities at private properties and public street ROWs. The private contractors conducted surveys using ground penetrating radar (GPR) and precision utility locating procedures to identify underground utilities, potential subsurface obstructions, and subsurface anomalies that might be former MGP structure foundations.

Once subsurface utilities had been marked out, soil boring and monitoring well locations were "cleared" to approximately 5 feet below grade using hand tools or a vacuum clearance machine. Aquifer Drilling and Testing (ADT) of New Hyde Park, New York and Boart Longyear Environmental and Infrastructure Drilling (Boart Longyear™) of Northborough, Massachusetts performed utility clearance excavations.

2.2 Surface Soil Sampling

Twelve surface soil samples were collected to evaluate areas of exposed soils within the footprint and adjacent to the Fulton Former MGP. Nine surface soils samples (FW-SS-01 through FW-SS-09) were collected as part of the RI scope of work. Three additional surface soil samples (FW-DSS-01 through DSS-03) were collected to characterize soils within the temporary investigation -derived waste (IDW) storage area. The surface soil sample locations are shown in Figure 3.

Each sample was collected using stainless steel or disposable sampling equipment, in accordance with the RIWP, within the top 2-inches of mineral soil with the exception of FW-SS-01. At the FW-SS-01 location, road base gravel was present within the top 6 inches. As a result, a shallow, surficial soil sample was collected from 0.5 to 1.0 foot beneath the gravel.

Each sample was placed into laboratory-supplied containers, which were stored in coolers with ice. Surface soil samples were analyzed by TestAmerica, a New York State Environmental Laboratory Approval Program (ELAP)-certified laboratory (Lab Id: 10602). This procedure was followed for all analytical samples collected during the Fulton RI and will not be repeated below.

Surface soils were analyzed for:

- VOCs via USEPA Method 8260B
- SVOCs via USEPA Method 8270C
- PCBs via USEPA Method 8082
- Pesticides via USEPA Method 8081
- Herbicides via USEPA Methods 8151
- Target Analyte List (TAL) metals via USEPA Method 6000/7000 series
- Total cyanide via USEPA Method 9012 and/or free cyanide [extraction by USEPA Method 9013A/and analysis by Micro-diffusion ASTM International (ASTM) Method D4282-02]

Table 6 presents a summary of laboratory analyses completed for each surface soil sample.

Surface soil QA/QC samples were not collected during the RI. Laboratory "batch" QA/QC data associated with the Fulton MGP sample delivery groups were used to support data validation.

2.3 Subsurface Explorations and Sample Collection

2.3.1 Test Pit Excavations

Eight test pits (FW-TP-02A, FW-TP-02B, and FW-TP-03 through FW-TP-08) were excavated using a rubber-tired backhoe. The test pits excavations were completed to evaluate the presence, configuration and contents of former underground gas oil tanks and the former 500,000-gallon oil tank at Parcel II, and the former gasholder at Parcel IV. Test pit locations are shown in Figure 3.

Test pit excavations were completed by Environmental Closures, Inc. Soils were excavated to the depth of the apparent water table that ranged from approximately 8.5 feet in FW-TP-02B to 13 feet bgs at FW-TP-07. One proposed test pit location (FW-TP-01) at Parcel IV was covered by roll-off bin containers and therefore was inaccessible. With NYSDEC approval, test pit (FW-TP-02A) was excavated along the perimeter of the holder at the entrance gate to the Parcel in lieu of completing test pit FW-TP-01. FW-TP-02A could not be completed to the water table because 1-inch pipes were encountered in the test pit.

Excavated soils were stockpiled on plastic sheeting located adjacent to the excavation. Soils were logged for visual and olfactory observations and photographed. Test pit logs are located in Appendix E.

One grab soil sample was collected from each test pit for laboratory analysis. Samples from test pits FW-TP-04 through FW-TP-08 [Parcel II] were collected within fill that exhibited physical impacts (sheen, staining and blebs) at the apparent water table. Samples from FW-TP-02B and FW-TP-03 (Parcel IV) were collected within fill at the apparent water table.

Samples were collected utilizing the backhoe bucket, which was decontaminated with a steam cleaner between excavations. Soil samples were analyzed for VOCs, SVOCs, TAL metals, herbicides, PCBs, pesticides, total and/or free cyanide as indicated in Table 6. One blind duplicate sample (from FW-TP-07 (13 to 13.2 feet) was also collected and submitted for the same suite of analyses. Analytical samples from FW-TP-02B and FW-TP-03 were not analyzed for herbicides, pesticides and PCBs due to an oversight during the field program.

The test pits were backfilled in reverse sequence so that the materials removed from the bottom of the test pit excavation were returned to the bottom and materials removed from the top were placed back on top. The soils were placed in lifts and compacted with the backhoe bucket and a plate compactor. At Parcel II (Thomas Greene Playground), the area surrounding test pit excavations FW-TP- 04 through FW-TP-08 was repaved and the basketball courts were restored in accordance with NYC DPR permit (No. B-12-09NF).

2.3.2 Soil Boring Installation

One hundred and five (105) soil borings were drilled during the RI to characterize subsurface geology, identify former MGP structures, assess the horizontal and vertical extent of visual impacts, evaluate the chemical impacts in soils, and enable the installation of monitoring wells. Soil boring locations are provided in Figure 3. The rationale for each soil boring location is provided in Table 6.

Soil borings were drilled and continuously sampled using Geoprobe® direct push, conventional hollow stem auger and resonant sonic drilling methods. Soil samples were collected using a 5-foot Macro-Core® sampler with disposable plastic sleeves for borings installed using a Geoprobe® drill rig. A carbon-steel split spoon sampler was used for borings completed using a conventional hollow stem auger drill rig. For resonant sonic drilling, soil samples were collected in a 10-foot or 20-foot core barrel and extruded into new clean disposable plastic sleeves. Geoprobe® drilling rods and Macro-Core® samplers and split spoon samplers were decontaminated using an alconox-tap water mixture and tap water rinse in accordance to the final RIWP. Resonant sonic and conventional auger rig drilling implements (i.e. casings, core barrel, augers, and drill rods) were decontaminated using a high pressure steam cleaner.

ADT provided direct push and conventional hollow stem auger drilling services. Boart Longyear™ provided resonant sonic drilling services.

The soils were logged and screened with an organic vapor analyzer equipped with a photoionization detector (PID). Visual and olfactory observations were recorded on field soil boring logs, in field books, and utilizing a field personal data assistant (PDA) equipped with pLog™ logging software. Final soil boring logs were prepared for each boring and are included in Appendix E.

In general, three subsurface soil samples were collected at each boring location. The first subsurface soil sample was collected within the top 5 feet from the sidewall of the hand-cleared boring within fill. The second sample was collected from the deeper boring interval that exhibited the greatest observed occurrence of tar, staining, odors, sheen, and/or PID readings. The third sample was collected from soils below observed impacts or at the completion depth of a boring. Additional soil samples were submitted in a number of borings to evaluate tar at different depth intervals within a particular boring.

If the boring was free of physical impacts, a sample was collected at the water table or at an elevation similar to that at the nearest impacted boring. Soil samples were collected from the depths of the screen intervals for monitoring wells FW-MW-21, FW-MW-22, and FW-MW-23 in accordance with the RI Addendum No. 2 work plan.

All subsurface soil samples were analyzed for VOCs, SVOCs, TAL metals, free cyanide and/or total cyanide (Table 6). Soil samples collected from suspected fill materials were also analyzed for PCBs, pesticides, and herbicides. The rationale used to determine selection of soil samples is detailed in Table 6.

One subsurface soil sample from FW-SB-03 (22.5 to 25 feet) was collected from a zone that was stained and exhibited strong diesel-like odors and was submitted for a forensic analysis of PAHs to Alpha Analytical (Alpha) in Mansfield, Massachusetts. Alpha is an ELAP laboratory (Lab Id: 11627). Forensic analysis included PAH analysis and selected biomarker compounds by gas chromatography (GC)/mass spectrometry with selected ion monitoring (modified USEPA Method 8270C) and total saturated hydrocarbons and total petroleum hydrocarbons by flame ion exchange (modified USEPA Method 8015B). The laboratory sample results are provided in Appendix F.

Each borehole not finished as a monitoring well was abandoned by filling the borehole with a cement/bentonite grout mixture tremied from the bottom of the borehole up to ground surface. Soil cuttings and excess soil samples were placed in 55-gallon United States Department of Transportation (USDOT)-approved drums for off-site disposal by National Grid at a properly permitted facility.

2.4 Monitoring Well Installation

Thirty monitoring wells and six temporary monitoring points were installed during the RI. Twenty-five shallow monitoring wells were installed to evaluate conditions at or near the observed water table. The wells were installed using hollow stem auger drilling methods and resonant sonic drilling methods.

The five remaining intermediate, deep, and Jameco aquifer monitoring wells were installed in monitoring well clusters (FW-MW-21, FW-MW-22 and FW-MW-23) along with their respective shallow wells using resonant sonic drilling methods (Figure 3). Monitoring well clusters are described below in order of decreasing depth:

- Three intermediate wells were installed as deep as 38 feet bgs. The well screens were installed approximately 5-feet below the accumulated sediment/native materials interface within the adjacent Gowanus Canal. The intermediate wells in this zone were given an “I” designation.
- One deep well (FW-MW-23D1) was installed to a depth of 117 feet bgs. While not present at the Site, the Gardiners Clay was observed in boreholes within about ½ mile from the Site; well FW-MD-23D1 was installed approximately 5 feet above the anticipated elevation of the Gardiners Clay. The well was installed at a similar depth as GC-MW30D1 that was installed during the USEPA Gowanus Canal RI.
- One Jameco well (FW-MW-23D2) was installed in the top 5-feet of the Jameco Aquifer at a total depth of 151.5 feet bgs.

All water table (shallow) monitoring wells were constructed with 2-inch inner diameter (ID) flush-threaded polyvinyl chloride (PVC) with 0.010-inch slotted screens. All screened intervals were 10 feet long.

The six temporary monitoring wells were installed within borings FW-SB-11, FW-SB-15, FW-SB-16, FW-SB-20, FW-SB-34 and FW-SB-43 and are designated with a GW (e.g., FW-GW-11 was installed in soil boring FW-SB-11). Each temporary well, with the exception of FW-GW-15, was constructed with 1-inch ID flush-threaded PVC with 0.010-inch slotted screens. FW-GW-15 was installed using 2-inch PVC well materials. The well screens were installed between 6 to 20 feet bgs.

Intermediate and deep wells (FW-MW-21I, FW-MW-22I, FW-MW-23I, MW-23D1 and FW-MW-23D2) were installed with 2-inch ID flush-threaded, 0.010-inch slotted screens, and screened intervals of 5 feet to be consistent with USEPA intermediate and deep monitoring well screen intervals and as specified in the Final Revised RIWP Addendum No. 2. FW-MW-21I and FW-MW-23I used PVC well materials. FW-MW-22I, FW-MW-23D1 and FW-MW-23D2 were constructed of stainless steel to prevent potential degradation by tar in the surrounding soils.

The annular space around each permanent well screen and approximately 2 feet above the well screen was backfilled with a washed, uniform silica sand to form a filter pack around the well screen. A2- to 3-foot bentonite clay seal was placed above the sand pack in each monitoring well. The bentonite seal in four monitoring wells (FW-MW-04, FW-MW-08, FW-MW-09, and FW-MW-22S) was 1-foot thick due to shallow groundwater conditions. The remaining annular space was filled to grade with a cement-bentonite grout slurry or concrete. Each monitoring well was fitted with a flush-mount locking road box set in a concrete pad. The well construction logs are included in Appendix E.

Table 7 provides information on well depths and elevations, top of casing information, and screen depths and elevations.

Following installation, each monitoring well was developed to remove silt and clays from the well and to stabilize the well filter pack. Development was done in accordance with the RIWP. Development waters were placed into USDOT-approved 55-gallon drums for off-site disposal by National Grid at a permitted disposal facility.

2.5 Air Monitoring

Perimeter air quality monitoring was conducted in accordance with the CAMP in the NYSDEC-approved Final RIWP.

Perimeter air-monitoring stations were placed upwind and downwind of the work zone during intrusive activities. A RAE Systems MiniRAE™ PID was used to monitor the levels of organic vapors in the ambient air and a Dusttrak™ monitor was used to monitor levels of airborne particulate matter (dust) that was less than 10 micron in size (PM-10). Each instrument was calibrated daily prior to use and set for data logging to record the data at 1-minute intervals. The data were downloaded to a computer. Portions of CAMP data collected during intrusive activities completed in August 2008 and June 2009 were lost due to a software issue.

There were instances when the air monitoring criteria data were exceeded. However, based on the field monitoring data, these were related to operation of gas-powered equipment and sawing of concrete pavement prior to commencing RI drilling activities. Diesel equipment exhaust particulates were the cause of elevated dust readings from time to time during the RI.

2.6 Groundwater Monitoring and Sampling

Groundwater monitoring activities consisted of the collection of depth-to-water measurements, gauging the wells for the presence of NAPL, and collection of groundwater samples for laboratory analyses.

2.6.1 Depth-to-Water Measurements and NAPL Gauging

Depth to groundwater measurements were collected from accessible monitoring wells at high tide and low tide on September 14, 2009, and May 19, 2011, and at high or low tide during six monthly gauging events, completed between July 2010 and December 2010, in support of the USEPA Gowanus Canal RI. Monitoring well gauging points are shown in Figure 3. Table 8 provides a summary of measured depth to groundwater and corresponding elevations of groundwater in each monitoring well. A discussion of groundwater elevations and groundwater flow is provided below in subsection 3.2. Monitoring wells were also gauged with an oil-water interface probe to determine if NAPL was present during these events. The remainder of this subsection is a discussion of the September 14, 2009, and May 19, 2011, gauging events.

Groundwater measurements at monitoring wells FW-MW-21S/I, FW-MW-22S, and FW-MW-23S, I, D1, D2 were collected on May 19, 2011, after they were sampled (between May 16 through May 18). This was a function of access limitations to private properties and access to USEPA monitoring wells.

Water level measurements were collected at low and high tide levels in the adjacent Gowanus Canal. Tidal stage information was obtained from the National Oceanic and Atmospheric Administration (NOAA) for a tidal gauging station located at Gowanus Bay. Three surface water gauging points (TBM-1, TBM-2 and TBM-3) were established along the Gowanus Canal bulkhead to measure tidal fluctuations (Figure 3).

- TBM-1 is located at the Union Street Bridge
- TBM-2 is located at the eastern intersection of Degraw Street and the Gowanus Canal
- TBM-3 is located along the bulkhead at Parcel VI

Two wells, FW-MW-10 and GC-MW-31I could not be gauged on May 19, 2011 because the area was flooded with water from heavy rains.

2.6.2 Groundwater Sampling

Groundwater samples were collected from the 30 newly-installed monitoring wells, three existing NYSDEC SC monitoring wells and six temporary monitoring wells over five different sampling events conducted between May 2008 and May 2011. The multiple groundwater sampling events were a function of property access and the two RIWP addendum scopes of work. A summary of monitoring well samples is provided below.

Sample Period	Work Plan Scope(s) [Location]	Wells Sampled
May to June 2008	Final RIWP [Parcel II and Street ROWs]	FW-MW-05R, FW-MW-06, FW-MW-07, FW-MW-08, FW-MW-09, FW-MW-16, and FW-GW-20,
May to June 2009	Final RIWP [Parcel I and Parcel IV]	FW-MW-01, FW-MW-02, FW-MW-17, and FW-GW-15
September 2009	Final RIWP and RI Addendum [No. 1] [Parcel I through VI and Street ROWs]	FW-MW-03 through FW-MW-10. FW-MW-12 through FW-MW-14, FW-MW-16, and FW-MW-18 through FW-MW-20 KSF-MW-02, KSF-MW-06 and KSF-MW-07,
February 2010 April 2010	Final RIWP [Parcel III and V]	FW-GW-11, FW-GW-16, FW-GW-34 and FW-GW-43
May 2011	RI Addendum No. 2 [Parcel VII and Street ROWs]	FW-MW-21 S/I, FW-MW-22 S, FW-MW-23 S/I/D1 and D2

Monitoring well locations are shown in Figure 3.

Purging

Low-flow purging and sampling of the RI monitoring wells and three of the SC monitoring wells was performed using either peristaltic pumps or bladder pumps and dedicated tubing in accordance with the Final RIWP. Temporary groundwater points were purged and sampled with peristaltic pumps. The inlet for the sample tubing was generally placed at the mid-point of the water column in the screen interval with the exception of five monitoring wells (FW-MW-03, FW-MW-04R, FW-MW-08, FW-MW-10 and FW-MW-18) during the 2009 sampling event. For these wells, the tubing inlet was set between 1.5 feet and 4 feet above the mid-point of the screen because of a field oversight. However, the groundwater from the wells stabilized as discussed below and the samples are representative groundwater samples.

Groundwater purged from each well was monitored for field parameters (temperature, pH, conductivity, dissolved oxygen, oxidation-reduction potential [ORP], and turbidity) using a closed flow cell and a multi-parameter water quality meter. Wells were sampled after the values of measured field parameters stabilized in accordance with the RIWP. Table 9 presents the final (stabilized) groundwater field parameters and physical observations of the purge water before the sample was collected. At least one well volume was purged from each well prior to sampling with the exception of FW-MW-21I and FW-MW-08 where approximately ¾ of a well volume was purged.

Purge water generated during the RI activities was placed into 55-gallon USDOT drums for off-site disposal by National Grid at a properly permitted disposal facility.

Sampling

After each monitoring well was purged, groundwater samples were collected and placed into pre-cleaned and preserved containers. VOC samples were collected with a dedicated/ disposable polyethylene bailer and rope that was lowered to the center of the screen interval to collect a sample. All other sample aliquots were collected using the peristaltic pump or bladder pump. Each sample container was placed into coolers and packed with ice. Groundwater samples were analyzed for VOCs, SVOCs, TAL metals, herbicides, pesticides, PCBs and total cyanide as indicated in Table 6.

Samples from three monitoring wells (FW-MW-1R, FW-MW-03, and FW-MW-22I) were not submitted for laboratory analysis because NAPL was observed during groundwater collection activities.

2.7 Hydraulic Conductivity Testing

In-situ hydraulic conductivity tests (slug tests) were completed at 11 monitoring wells that were screened across the shallow (S), intermediate (I) and deep portion (D1) of the Upper Glacial Aquifer and the Jameco Aquifer (D2).

Rising head tests were completed on shallow monitoring wells. Rising and falling head tests were completed on monitoring wells installed in intermediate and deep portions of the Upper Glacial Aquifer and on monitoring well FW-MW-23D2 in the Jameco Aquifer.

Hydraulic conductivity was estimated using the Bouwer and Rice method (Bouwer, Rice, 1976; Bouwer, 1989). The results of the slug tests completed as part of the Fulton MGP RI are summarized in Table 10. Slug test calculations are provided in Appendix G.

2.8 Soil Vapor Sampling

Thirteen soil vapor points (FW-SV-01 through FW-SV-13) were installed at Parcels I through Parcel V and soil vapor samples were collected from each point. The soil vapor points were installed to evaluate the potential for soil vapor intrusion (SVI) into on-site buildings and the soil vapor conditions beneath the former Fulton MGP Site. FW-SV-01 to FW-SV-07 and FW-SV-11 to FW-SV-13 were sub-slab soil vapor points installed through the concrete building slab to screen soil vapor beneath the on-site buildings. FW-SV-08, FW-SV-09 and FW-SV-10 were completed as temporary exterior soil vapor points to screen soil vapor outside buildings.

Temporary sub-slab soil vapor points (FW-SV-01 through FW-SV-04) were installed at Parcel I during July 2008. Each temporary sub-slab soil vapor point was drilled with an electric hammer drill. The temporary points were constructed with a piece of dedicated Teflon tubing with the opening positioned just below the bottom of the building slab. Modeling clay was used to seal around the tubing at the top of the building slab. The temporary soil vapor points were replaced with permanent sub-slab monitoring points and re-sampled during March 2009.

Permanent sub-slab soil vapor points were installed at each sub-slab soil vapor sample location at Parcels I, II and V. The permanent points were installed by coring through the concrete building slab with a concrete coring machine. Each point was constructed with a segment of 3/8-inch stainless steel tubing with the opening positioned just below the bottom of the building slab. Each sub-slab soil vapor point was backfilled with sand, a bentonite seal and non-shrinking concrete seal. Each point was constructed with a 2-inch flush-mounted manhole.

Exterior soil vapor points were installed using hand tools or a Geoprobe® drill rig to a depth of approximately 4 to 9 feet bgs (approximately 1 foot above the observed apparent groundwater table). Each temporary soil vapor point was constructed with a 6-inch Geoprobe® stainless steel screen fitted with Teflon tubing to the surface. Each vapor-sampling screen was backfilled with clean sand to approximately 6-inches above the screen and sealed with granular bentonite clay seal. The points were removed following sampling.

Each soil vapor sample was collected in an individually certified, 6-liter capacity SUMMA® canister. Each canister had a laboratory-supplied flow controller calibrated for an 8-hour sample period. The flow rate was less than 0.2 liters per minute. An enclosure that was enriched with helium tracer gas was used, as described in the NYSDOH SVI Guidance document. The samples were shipped to TestAmerica Laboratory in Knoxville, Tennessee and were analyzed for VOCs by USEPA Method TO-15 (including naphthalene) and helium by ASTM Method 1945. A split sample was collected at FW-SV-10 and submitted to Alpha for analysis for TO-15 and helium. A total of four duplicate soil vapor samples were collected.

Soil vapor samples were collected at Parcel I in July 2008, Parcel II in May 2008 and Parcel IV in June 2009 because of property access limitations.

2.9 Indoor Air Sampling

Indoor air was sampled at eight locations (FW-IA-01 to FW-IA-08) within on-site buildings. Indoor air samples were collected during soil vapor sampling to evaluate potential SVI into on-site buildings.

The indoor air samples were collected using individually-certified 6-liter SUMMA® canisters. Each canister was equipped with a laboratory-supplied flow controller that was calibrated for an 8-hour sample period. The flow rate for each air sample did not exceed 0.2 liters per minute. The inlets of each canister were positioned at the approximate breathing height of 3 to 5 feet above ground.

The air samples were picked up by TestAmerica-Connecticut couriers or shipped directly to TestAmerica Laboratory in Knoxville, Tennessee. The samples were analyzed for VOCs by USEPA Method TO-15 (including naphthalene). Two blind duplicate indoor air samples were collected at locations FW-IA-01 and FW-IA-03 and analyzed.

Inventories of products, supplies, and equipment that could affect the indoor air were conducted during SVI sampling activities in general accordance with NYSDOH's Indoor Air Quality Questionnaire and Building Forms. The forms are contained in Appendix H.

2.10 Ambient (Outdoor) Air Sampling

Ambient (outdoor) air was sampled at four locations (FW-OA-1 to FW-OA-04). These samples were collected during soil vapor/indoor air sampling to determine outdoor air concentrations and the potential to influence indoor air quality.

The ambient outdoor air samples were collected using individually-certified 6-liter SUMMA® canisters. Each canister was equipped with a laboratory-supplied flow controller that was calibrated for an 8-hour sample period. The flow rate for each air sample did not exceed 0.2 liters per minute. The inlets of the canisters were positioned at the approximate breathing height of 3 to 5 feet above ground. At Parcel V, the outside air sample was placed approximately 7 feet above ground in order to secure the SUMMA® canister to the building and to place it out of the way of tenant operations.

The air samples were picked up by TestAmerica-Connecticut couriers or shipped directly to TestAmerica Laboratory in Knoxville, Tennessee. The samples were analyzed for VOCs by USEPA Method TO-15 (including naphthalene).

2.11 Data Validation and Management

Analytical results for the samples submitted to TestAmerica were validated using appropriate USEPA guidance that is consistent with New York State Analytical Services Protocol (NYSASP) Category B guidance. The analytical data presented in Tables 11 through 14 include qualifiers based on the validation. All data were found to be valid and usable for the purposes of this RI with the exception of values rejected as indicated in Tables 11 through 14. The data usability summary reports (DUSRs), chain-of-custody forms and the validated laboratory Form I reports are included in Appendix F.

2.12 Survey

RI sample locations were surveyed by a New York State-licensed land surveyor (NY LS #: 050146). The survey was conducted to A-2 standards of accuracy, with an approximate horizontal and vertical precision of ±0.02 feet. Surveying of FW-SB-14 [Parcel IV] was not possible because roll-off bins were stacked over the boring location at the time of the survey.

The former Fulton MGP RI points and accessible USEPA RI monitoring wells were located utilizing differential global positioning system (GPS) observations. Two GPS base station control points (CP-01 and CP-02) were established at Parcel II on the east side of the Gowanus Canal and within the Sackett Street ROW. A number of geodetic baselines were subsequently established from this base station, and were then occupied by a total station to locate individual points.

Point coordinates were referenced to the New York State Plane Coordinate System-East Zone horizontal datum and elevations were referenced to NAVD88. The vertical survey datum control for the former Fulton MGP points was originally established utilizing elevations derived from the two GEI-established GPS control points. During the preparation of the RI report, an elevation discrepancy was discovered for USEPA monitoring wells that GEI surveyed.

- Points located to the east of the Gowanus Canal that were referenced to CP-01 were 3.21 feet higher (+ 3.21 feet) than USEPA published monitoring well elevations.
- Points located to the west of the Gowanus Canal that were reference to CP-02 were 0.37 feet lower (-0.37 feet) than USEPA published monitoring well elevations.

The monitoring wells were re-surveyed using USEPA control point (BM-1) located on the Carroll Street Bridge to the south of the Fulton MGP Site. BM-1 was utilized by USEPA for Gowanus Canal RI activities. BM-1 was established by the GEOD Corporation (NYS LS #: 50203). According to GEOD Corporation, BM-1 had an elevation of 8.15 feet NAVD88.

3. Site Geology and Hydrogeology

This section describes the geology and hydrogeology at the former Fulton MGP Site and the RI study area. Information provided in this section is based upon specific subsurface soil and groundwater data collected during the RI of the former Fulton MGP. Information from NYSDEC's SC, KeySpan's Gowanus Canal RI (GEI, 2009), and USEPA's Gowanus Canal RI (HDR, et al, 2011) is also incorporated into this section.

3.1 Geology

Six major stratigraphic units, in order of increasing depth, were identified during the RI: (1) fill, (2) alluvial/marsh deposits, (3) glacial outwash deposits, (4) Gardiners Clay, (5) Jameco Gravel, and (6) Fordham Gneiss. Although the Gardiners Clay wasn't encountered, soil samples identified the presence of shells suggesting that the unit is in close proximity to the Site (shells are reported to be associated with the unit).

The marsh deposits described herein include the highly organic former wetland materials as well as associated fine-grained silts, clays, and peat material. For purposes of this report, the marsh deposits will also be referred to as the "meadow mat layer" because of the colloquial use of the term in discussions with the NYSDEC. Figure 10 provides a summary of the extent of the meadow mat layer. Cross sections A-A' to E-E'(Figures 11 and 12) were developed to illustrate the geology underlying the RI study area. The distribution of chemicals and the observations of physical impacts are described in Section 4. Detailed geologic descriptions for each soil boring log and monitoring well construction details are provided in Appendix E.

3.1.1 Fill

Fill was encountered in soil borings drilled throughout the entire RI study area. The fill consists primarily of loose, non-cohesive sand and silty-sand with some gravel mixed with brick, concrete, coal fragments, wood, ash, metal fragments, and debris. Fill ranged from approximately 5-feet thick at multiple locations to approximately 30-feet thick at FW-SB-45 (Parcel VIII) and in FW-MW-13 adjacent to Parcel V.

Foundations of former MGP-related structures were also encountered in the fill. The foundations were encountered as shallow as 1 foot (Parcel IV) and as deep as 31 feet bgs. The foundations are further discussed in Section 4 and are depicted in profile on the cross sections (Figures 11 and 12).

3.1.2 Alluvial/Marsh Deposits

Alluvial/marsh deposits, where present, were found beneath a layer of fill. The deposits consist of sub-units of alluvial sand and organic marsh (meadow mat) materials which including fine-grained soils including silt, silt-clay, and clay and peat. Based on historical maps, these deposits are believed to be associated with a former marsh (possibly inter-tidal) located adjacent to the former Gowanus Creek. A map of the area in 1849 (Figure 5) indicates that the headwaters of Gowanus Creek originally flowed beneath and through portions of the RI Parcels, forming a meandering channel with adjacent wetlands.

The marsh deposits were encountered throughout the investigation area with the exception of locations near 3rd Avenue and within Parcel I. The extent of marsh deposits based upon soil boring observations is shown in Figure 10. The marsh deposits were found at the approximate elevation (approximately -11 feet) of the anticipated bottom of the former Gowanus Creek and are consistent with a former active stream depositional system and an associated lower energy marsh environment. The thickness of the marsh deposits ranged from 0.25 feet in GC-GP-06 adjacent to the eastern Gowanus canal bulkhead to 17 feet at FW-SB-23 (Parcel VII). The deposits were observed as shallow as 4 feet bgs [elevation 1.79 feet] in GCMW-02S and extended to a maximum depth of 39.5 feet bgs [elevation -20.08 feet] at boring FW-MW-12 [Parcel V] (Figure 10).

Alluvial sand deposits were encountered at similar elevations as the marsh deposits. Based upon the elevation and thickness of the meadow mat, the alluvial sands appear to occur approximately between elevations -3 feet to -11 feet. This corresponds to a depth of approximately 17 feet bgs. The alluvial deposits generally consist of widely graded sand that is grey to brown in color. Alluvial sands transition into underlying glacial outwash deposits.

3.1.3 Glacial Deposits

Glacial deposits were encountered beneath the alluvial/marsh deposits and fill and above the Jameco Gravel. The glacial deposits can be classified into two sub-units, a predominantly sandy glacial outwash unit and finer-grained glacial till unit. Glacial outwash was the most extensive unit encountered during the RI and is sporadically inter-bedded with glacial till. These units are depicted on cross sections A-A' through E-E', (Figures 11 and 12).

The glacial outwash sands are typically brown to gray, loose, non-cohesive, well-sorted, fine to coarse sands with varied amounts of gravel and trace silt. A cobble zone was encountered between approximately 63 and 70 feet bgs in FW-SB-49 and between 57 and 58 feet bgs in FW-SB-46 to the west of the Gowanus Canal. The glacial outwash unit generally extended to the top of the Jameco Gravel, which was present between approximately 125 and 145 feet bgs. Isolated layers of glacial till were encountered within the glacial outwash.

Layers of glacial till, likely associated with the advance and retreat of the Harbor Hill terminal moraine (located south of the Site), were encountered within the glacial outwash unit on Parcels I through Parcel III, Parcel VI and Parcel VIII and within borings completed within public street ROWs to the east and to the west of the Gowanus Canal. The isolated layers of glacial till represent a brown to red-brown, poorly-sorted unit consisting of silt and fine to coarse sand. Layers of glacial till were not continuous and were primarily encountered to the northeast of the former Fulton MGP Site and to the west of the Gowanus Canal. The layers were encountered as deep as 122 feet in the boring for GC-MW-30D2. The thickness of the glacial till ranged from 0.4 feet in boring FW-MW-13 [Parcel V] and as thick as 34 feet in boring FW-SB-39 beneath the Douglass Street ROW. The till layers were encountered with increasing depth and frequency in borings completed to the north and northeast of the former Fulton MGP Site and in borings completed to the west of the Gowanus Canal(cross-section C-C', Figure 11).

3.1.4 Gardiners Clay

The Gardiners Clay was not encountered during the RI. However, a 1.5-foot-thick layer of grayish-brown silty-sand that contained approximately 50 percent shells was encountered at boring GCMW-01D02 between 122.5 to 124 feet bgs [elevation -113.8 to -115.3 feet] at a depth consistent with the Gardiners Clay unit observed during investigations at the Citizens Gas Works MGP, approximately 0.5 mile to the south.

3.1.5 Jameco Gravel

The Jameco Gravel was encountered beneath the glacial outwash and potential layer of the Gardiners Clay adjacent to the Gowanus Canal (cross-section B-B' in Figure 11). The Jameco Gravel consists of loose, non-cohesive, gray, widely graded medium to coarse sand and coarse gravel. The materials encountered are consistent with published descriptions (Cartwright, 2002) and observations in deep borings completed by GEI during the RI of the Citizens Gas Works Former MGP Site (GEI, 2005). The Jameco Gravel was encountered from approximately 124 feet in GCMW-30D2 at Parcel I to 160 feet bgs at the termination of FW-SB-51 [approximately elevation -115.3 to -153 feet].

3.1.6 Fordham Gneiss

Fordham Gneiss bedrock was found in GCMW-30D2 at Parcel I (cross-section B-B' in Figure 11). The Fordham Gneiss is a metamorphosed, medium to coarse-grained rock that underlies Brooklyn and Manhattan. The bedrock encountered at the Site is consistent with published descriptions (Cartwright, 2002). Highly weathered Fordham Gneiss was encountered at a depth of approximately 151 feet bgs [elevation -142 feet] and bedrock was observed at a depth of 159 feet bgs [approximately elevation-150 feet].

3.2 Site Hydrogeology

The Site hydrogeology is discussed in terms of the two groundwater aquifers (Upper Glacial and Jameco) that underlie the former Fulton MGP and vicinity. Groundwater elevation measurements are provided in Table 8. Groundwater measurements recorded by USEPA during Gowanus Canal RI activities between July and December 2010 is also included in Table 8.

The Upper Glacial Aquifer is generally an unconfined aquifer; however, deeper portions of the aquifer exhibit semi-confined aquifer conditions. This is consistent with previous investigations completed by GEI near the Gowanus Canal and published studies completed by Buxton, *et al*. (1981) and Cartwright (2002). The Upper Glacial Aquifer has been subdivided into shallow, intermediate, and deep groundwater zones. Groundwater contour maps of the shallow (water table) and the intermediate zones of the Upper Glacial Aquifer have been prepared for high and low tide stages on May 19, 2011 (Figures 14, 15, 16).

The Jameco Aquifer is a regionally semi-confined aquifer and is regarded as a single zone aquifer because just two monitoring wells were installed and screened within its upper portion.

Tidal effects were observed on groundwater elevations in the Upper Glacial Aquifer and the Jameco Aquifer. Figures 14 through 16 depict the low tide and high tide groundwater contour maps for the shallow and intermediate zones of the Upper Glacial Aquifer. Table 8 presents a summary of depths to groundwater and groundwater elevations at high and low tide.

Horizontal hydraulic conductivities were calculated using Bouwer-Rice methods based upon in-situ (slug) tests completed during the former Fulton MGP RI and the USEPA Gowanus Canal RI. Slug tests were performed in nine shallow (water table) wells and six intermediate wells, and three deep wells within the Upper Glacial Aquifer and two wells screened within the Jameco Aquifer. Upon analysis, GEI determined that the slug test data for the deep wells in the Upper Glacial Aquifer and the wells screened in the Jameco Aquifer were not of sufficient quality to allow analysis of hydraulic conductivity. As a result, hydraulic conductivities were only calculated for the shallow and intermediate Upper Glacial Aquifer wells. A summary of hydraulic conductivity values is presented in Table 10. Appendix G includes the slug test data with the associated hydraulic conductivity calculations.

Vertical hydraulic head differentials (vertical head potential) were also calculated between zones of the Upper Glacial Aquifer and the Jameco Aquifer to assess the potential for groundwater to migrate either upward or downward between the aquifers or between zones of the Upper Glacial Aquifer. If a confining layer is present between two zones, groundwater may not actually move across the confining layer and, therefore, the calculated vertical head potential will represent the difference in hydraulic pressures between the two zones.

3.2.1 Upper Glacial Aquifer

To evaluate the conditions within the Upper Glacial Aquifer, monitoring wells were installed in three groundwater zones (shallow, intermediate, and deep) at generally consistent elevations (within each zone). Table 8 presents a summary of depths to groundwater and groundwater elevations at high and low tide.

3.2.1.1 Upper Glacial Aquifer – Shallow (Water Table) Zone

The shallow groundwater zone resides in fill and alluvial/marsh deposits. Well screen intervals within the shallow zone ranged between approximately 9 feet to –13 feet. Groundwater elevations from the May 19, 2011 and September 9, 2009 gauging events and groundwater level information collected as part of USEPA Gowanus Canal RI activities between July and December 2010 are presented in Table 8. Figure 14 presents the groundwater contours for the shallow (water table) zone at high tide on May 19, 2011. Figure 16 depicts the contours at low tide.

Approximately 4 inches of rain were recorded at the NOAA Central Park Weather Station [KNYC] (Weather Underground, 2011) between May 15 and May 18, 2011. As such, water table elevations were somewhat elevated on May 19, 2011 compared to prior gauging events. However, the relationships between water levels remained consistent.

Water Level Summary and Groundwater Flow

Water table elevations (shallow zone) ranged from elevation -1.76 feet at GC-MW-03S [near the west side of the Canal] to 8.03 feet at FW-MW-14 [Parcel V] during the May 19, 2011 groundwater gauging event. Elevated water levels were observed in monitoring wells during May 19, 2011, gauging event which is likely attributable to excessive rainfall earlier during the week. The excessive rainfall overwhelmed the surface water drainage system and flooded Thomas Greene Playground on May 18, 2011. Figure 14 shows the groundwater contour maps for the shallow (water table) zone at high tide on May 19, 2011. Figure 16 depicts the contours at low tide.

The apparent water table elevations inside the gasholder foundations at Parcel III and Parcel IV are higher than outside the gasholder foundations at the Parcels.

- At Parcel III, the observed apparent water table inside the gas holder foundation was approximately elevations 7.86 feet NAVD88 (FW-SB-12) and 5.30 feet (FW-SB-13).

Outside the holder it was measured in temporary well (FW-GW-11) the groundwater elevation was elevation 8.04 feet.

- At Parcel IV, the observed apparent water table inside the holder foundation was at approximately elevation 6.95 feet based upon soil boring FW-SB-15. Outside the holder foundation, the water level was observed at approximately elevation 4.10 feet in nearby well FW-MW-05.

The gas holder foundations appear to be intact based on higher apparent water table elevations inside the holder than outside the gas holder foundations.

Tidal fluctuations in the shallow zone of the Upper Glacial Aquifer adjacent to the Fulton Former MGP Site ranged from no change in FW-MW-04 during the September 12, 2009 gauging event to 1.66 feet in FW-MW-01 [Parcel I] during the May 19, 2011 gauging event. FW-MW-04 is located approximately 300 feet to the southeast of the Gowanus Canal while FW-MW-01 is located approximately 35 feet to the southeast of the Gowanus Canal. The greatest tidal change of 4.85 feet was observed within GC-MW-03S adjacent to the western bulkhead of the Gowanus Canal. Overall, the greatest tidal fluctuations were observed in monitoring wells located adjacent to the Gowanus Canal bulkhead. Tidal fluctuations were less than 0.05 feet within 235 feet of the Gowanus Canal.

The shallow groundwater near the Site, on the east side of the Canal, generally flows westward toward the Gowanus Canal at high and low tide levels based upon groundwater elevation data (Figure 14 and 16). Shallow groundwater on the west side of the Gowanus Canal flows to the east and south toward the Canal. The groundwater contours show a potential area of mounded water in the water table portion of the Upper Glacial Aquifer beneath Parcel II which is likely attributable to on-site drainage and by the presence of less permeable meadow mat deposits and fill underlying the area (Figures 11 and 12). The observed lateral extent of the meadow deposits is shown in Figure 10 roughly coincides with the presence of the observed groundwater mound. Shallow groundwater flow just south of Parcel V also appears to be potentially affected by the presence of the buried trace of the former Gowanus Creek, with groundwater flow shifting southerly in this area (Figures 14 and 16).

Hydraulic Gradient and Average Linear Flow

Overall, the average hydraulic gradient of the shallow groundwater aquifer range from 0.0017 foot/foot to 0.024 foot/foot. Away from the bulkhead, steeper hydraulic gradients were generally located to the northeast of the Fulton MGP Site and to the north of Douglass Street and at Parcel V. Shallower gradients were generally occurred to the northwest of the Nevins Street ROW beneath Parcels I and VI and beneath Parcel II in the vicinity of Thomas Greene Playground (Figure 14).

A localized, tidally influenced hydraulic gradient change was observed adjacent to the eastern and western bulkheads of the Gowanus Canal in the following monitoring wells:

- FW-MW-01R [adjacent to Parcel I], FW-MW-01 [Parcel I], and FW-MW-18 [Union Street ROW] to the east of the Gowanus Canal.
- GC-MW-03S and GC-MW-34S in the vicinity of Sackett Street ROW to the west of the Gowanus Canal.

The tidally influenced hydraulic change was observed within 20 feet of the bulkhead in the vicinity of the former Fulton MGP Site and approximately 100 feet of the bulkhead in the vicinity of Union Street.

The hydraulic conductivity (K) of the water table portion of the Upper Glacial Aquifer was estimated using data generated from a well permeability tests (rising head slug test) conducted on monitoring wells (FW-MW-01/GC-MW-30S and FW-MW-09). FW-MW-01/GC-MW-30S was screened in fill that that consisted of silty sand to widely graded sand. FW-MW-09 was screened within fill and soils that were characterized as widely graded sand with silt. The hydraulic conductivity was calculated for FW-MW-01/GC-MW-30S as 2.8 feet/day and was calculated for FW-MW-09 as 56.78 feet/day (Table 10) Appendix G for hydraulic conductivity calculations.

Average linear flow velocities for the water table aquifer were calculated based on the measured hydraulic conductivities and the horizontal hydraulic gradients using the following equation:

$$V = Ki/n$$

where:

K = hydraulic conductivity of the formation
i = lateral hydraulic gradient
n = effective porosity of the formation

The following values were used to calculate a range of average linear flow velocities for the water table portion of the Upper Glacial Aquifer.

Parameter	Value	Notes
Effective porosity (n):	30%	Assumed literature value (Fetter, 1988)
Lateral hydraulic gradient:	0.0017 (western portion of Parcel III near Sackett Street and Parcel I) to 0.029 (northwest Parcel VII near GC-MW-34S to FW-MW-19 within Sackett Street ROW)	Determined from contour map (Figure 14)
Hydraulic conductivity (K):	2.8 (ft/day) 22.4 (ft/day)	Slug test value from FW-MW-01/GC-MW-0S Slug test value from FW-MW-09

The estimated average linear flow velocities ranged from 5.79feet per year in the southwestern portion of Parcel III and Parcel I near FW-MW-01/GCMW-30S to approximately 790.35 feet per year to the northeast of the Site north of Douglass Street near GCMW-33 and FW-MW-19 within the Nevins Street and Butler Street ROWs.

Tidal Study Summary

The USEPA completed a tidal study as part of the Gowanus Canal RI (HDR et. al., 2011). Three monitoring wells were included in the USEPA's tidal study near the Fulton MGP Site:

- GCMW-03S - adjacent to western bulkhead of Gowanus Canal
- GCMW-04S - Sackett Street ROW near the intersection of Bond Street
- GCMW-34S -Nevins Street ROW

Groundwater levels in GC-MW-03S experienced groundwater fluctuations of 3.75 feet between high and low tide levels during the tidal study. The surface water levels in the Gowanus Canal fluctuated (between low and high tides) as much as 4.3 feet during the tidal study conducted during the USEPA Gowanus Canal RI. A tidal efficiency of 89% was calculated between the water level changes in GC-MW-03S and the Gowanus Canal. The tidal study reported shallow wells near the Canal exhibited potentiometric oscillations correlating with tidal changes; however, the oscillations were estimated to attenuate to less than 0.1 feet within shallow wells more than 300 feet from the Canal which is consistent with changes observed during the former Fulton MGP RI.

3.2.1.2 Upper Glacial Aquifer – Intermediate Zone

The intermediate groundwater zone resides in glacial outwash deposits. Monitoring well screen intervals within this zone ranged from elevation –17 to –36 feet. Thirteen monitoring wells were installed in the intermediate zone as follows:

Fulton MGP RI- Three Monitoring Wells

- FW-MW-21I, FW-MW-22I, and FW-MW-23I

USEPA Gowanus Canal RI- Eight Monitoring Wells

- GCMW-01I through GCMW-04I
- GCMW-30I through GCMW-34I

Water Level Summary and Groundwater Flow

The groundwater elevations within the intermediate groundwater zone ranged from elevation 0.87 feet at GC-MW-30I [Parcel I] during the October 22, 2010 event (low tide) to elevation

3.06 ft at FW-MW-21I [corner of Bond and Degraw Streets] during the May 19, 2011 groundwater gauging event. The highest groundwater levels were observed on May 19, 2011 (high tide) that coincided with the elevated rainfall in the days prior to gauging.

Under high tide conditions on May 19, 2011, groundwater in the intermediate groundwater zone of the Upper Glacial Aquifer generally flows toward the Gowanus Canal and converges on a southerly flow path in the vicinity of Parcel I, just to the east of the Canal (Figure 15). At low tide conditions, groundwater flow in the intermediate zone is more southeasterly (Figure 16). It is possible that the groundwater flow in the intermediate zone of the Upper Glacial Aquifer continues to be influenced by the presence of the former outwash channel that was scoured by glacio-fluvial processes, and; therefore, is converging slightly to the east of the current alignment of the Gowanus Canal, while the overall discharge direction is south-southeasterly toward Gowanus Bay.

Tidal fluctuations within the intermediate zone of the Upper Glacial Aquifer during the May 29, 2011 groundwater gauging event ranged from 0.04 feet at GCMW-33I in the Nevins Street ROW to 1.03 feet in GCMW-03I along the western bulkhead of the Gowanus Canal.

Hydraulic Gradient and Average Linear Flow

The average hydraulic gradient of the intermediate groundwater zone ranged between 0.0018 foot/foot on the eastern side of the Gowanus Canal to 0.0020 foot/foot on the western side of the Canal.

The hydraulic conductivity of the intermediate groundwater zone was estimated using data generated from multiple well permeability tests (slug tests) conducted on monitoring wells that are screened within glacial outwash. The hydraulic conductivity (K) was calculated for GC-MW-31I as 15.0 feet/day and was calculated for GC-MW-31I as168 feet/day (see Appendix G for hydraulic conductivity calculations).

A similar calculation of the average linear flow velocity for the intermediate groundwater zone was performed.

The following values were used to calculate a range of average linear flow velocities for the intermediate portion of the Upper Glacial Aquifer.

Parameter	Value	Notes
Effective porosity (n)	30%	Assumed literature value
Lateral hydraulic gradient	0.00072 between FW-MW-23I and GC-MW-31I to 0.002 (GCMW-04I to GCMW-30I)	Determined from contour map (Figure 15)
Hydraulic conductivity (K)	15 (ft/day) 168 (ft/day)	Slug test value from GCMW-31 Slug test value from GCMW-30I

The average linear flow velocity of the groundwater was estimated to be 13.14 to 408.8 feet per year.

3.2.1.3 Upper Glacial Aquifer – Deep Zone

The deep groundwater zone consists of glacial outwash deposits. Two wells, FW-MW-23D1 and GCMW-30D1, were screened approximately elevation -103 to -110 feet.

Groundwater elevations within the deep groundwater zone ranged from elevation 2.51 feet (low tide) at GCMW-30D1 [Parcel I] to elevation 3.46 feet (high tide) at FW-MW-23D1 [Parcel VII] during the May 19, 2011 groundwater gauging event. Tidal fluctuations within the deep zone of the Upper Glacial Aquifer ranged from 0.07 feet in FW-MW-23D1 to 0.37 feet in GCMW-30D2.

Groundwater flow direction in the deep groundwater zone of the Upper Glacial Aquifer cannot be determined because only two deep wells were installed within the study area; however, flow data from nearby sites and the regional groundwater flow direction suggest that the flow in the deep zone should be southwesterly toward Gowanus Bay. As mentioned above, the hydraulic conductivity for the deep zone of the Upper Glacial Aquifer could not be determined from the single well permeability test (slug test) data. Average linear flow velocity in the deep zone of the Upper Glacial Aquifer could not be calculated because the conductivity couldn't be calculated and because flow direction could not be determined from the two deep monitoring wells.

3.2.1.4 Jameco Aquifer

The Jameco Aquifer underlies the Upper Glacial Aquifer and regionally, the Gardiners Clay serves as a confining unit between these two aquifers. However, the Gardiners Clay was not encountered during the RI. Cartwright, 2002, has noted that where the Gardiners Clay is absent, the Jameco Aquifer will likely exhibit similar hydrologic conditions as the Upper Glacial Aquifer. Therefore, as discussed above, the Jameco Aquifer beneath the Site is not expected to behave as a completely separate aquifer, but exhibits groundwater elevations slightly higher than those observed in monitoring wells screened in the deep portion of the Upper Glacial Aquifer due to semi-confined artesian pressure within the aquifer.

Two monitoring wells were installed within the upper portion of the Jameco Aquifer. The monitoring wells (FW-MW-23D2 and GCMW-30D2) were screened from approximately 142 feet to 151 feet bgs [elevation –133 feet to –145 feet,] (Table 8).

Groundwater elevations within the Jameco aquifer ranged between elevation 3.88 feet at low tide and elevation 3.90 feet at high tide in FW-MW-23D2 during the May 19, 2011 gauging event. In GCMW-30D2, groundwater levels ranged between 2.12 feet on July 26, 2010 to elevation 3.24 feet during the May 19, 2011 gauging event. Tidal fluctuations within the Jameco Aquifer ranged from 0.02 feet at FW-MW-23D2 to 0.37 feet at GCMW-30D2.

Groundwater flow directions could not be directly determined because only two wells were installed in the Jameco Aquifer; however, flow direction is expected to be southerly based upon regional groundwater flow information. Hydraulic conductivity could not be calculated from the single well permeability (slug test) data collected. As such, average linear flow velocity could not be determined.

3.2.2 Vertical Head Potentials

The groundwater flow for a specific aquifer or flow zone is typically depicted on a contour map that represents the potentiometric surface of the groundwater. From such a map, one can infer the direction of groundwater flow. The potential for vertical groundwater flow between aquifers, or groundwater flow zones, is often of interest in assessing how contaminants may migrate from one aquifer, or flow zone, to another.

Calculation of the vertical hydraulic head differentials (vertical head potential) between two aquifers (or groundwater flow zones) provides a means to assess the potential for groundwater to migrate (either upward or downward) between separate aquifers or flow zones. It is important to note that if a confining layer is present between two aquifers that groundwater may not actually move across the confining layer and, therefore, the calculated vertical head potential will simply represent the difference in hydraulic pressures between the two aquifers. Vertical head potential is calculated by dividing the magnitude of head difference between two wells by the linear distance between the elevations of the center of the monitoring well screen for each well using the following equation:

$$i_v = dh/dl$$

Where:

i_v = the vertical hydraulic head differential between two groundwater flow zones
dh = the change in groundwater head (elevation) between two wells (ft)
dl = the linear distance between the elevations of the centers of two well screens

Vertical head potentials were calculated for well clusters screened between:

- Shallow and intermediate zones of the Upper Glacial Aquifer
- Intermediate and deep zones of the Upper Glacial Aquifer
- Deep zone of the Upper Glacial Aquifer and the Jameco Aquifer.

Table 15 presents a summary of the calculated vertical head potentials for each well pair. A negative value of vertical gradient represents potential downward groundwater flow between the aquifer/groundwater zones and a positive vertical gradient represents potential upward flow between the aquifer/groundwater zones.

Shallow and Intermediate Zone of the Upper Glacial Aquifer

Upward head potentials were observed in the following well pairs between the shallow and intermediate zones of the Upper Glacial Aquifer.

- FW-MW-01 (GCMW-30S)/GCMW-30I [Parcel I]
- FW-MW-10(FW-MW-31S)/FW-MW-31I [Parcel VI]
- FW-MW-21S/I, [Degraw Street]
- FW-MW-23S/I [Parcel VII]

The upward head potentials ranged from 0.001 in the FW-MW-21 pair to 0.097 in the GC-MW-01S/I pair.

Downward vertical head potentials were observed in:

- FW-MW-16(GCMW-32S)/GC-MW-32I [Parcel II]
- GC-MW-33S/GCMW-33I [Nevins Street ROW]
- GC-MW-04S/I [Sackett Street ROW]

The downward head potentials ranged from -0.009 in the GCMW-04 well cluster to -0.151 in FW-MW-16(GCMW-32S)/GCMW-32I well pair. The consistently downward vertical head potentials provide further evidence that the meadow mat materials have resulted in a mounded water condition in the shallow zone at Parcel II and potentially in other areas where the meadow mat materials are present.

Tide fluctuations influenced the vertical head potential in the GCMW-02S/I, GCMW-03S/I and FW-MW-22S/I well pairs. In general, downward head potentials were observed at high tide while upward head potentials were observed at low tide.

Intermediate and Deep Zone of the Upper Glacial Aquifer

Upward head potentials were observed in both of the two well pairs (FW-MW-23 I/D1 and GCMW-30 I/D1) installed in the intermediate and deep zones of the Upper Glacial Aquifer. The upward head potentials ranged from 0.006 at high tide on September 29, 2010and May 19, 2011to 0.19 at low tide on May 19, 2011 in the GCMW-301/D1 cluster. The upward head potential in the FW-MW-23I/D1 cluster was 0.009 at high tide to 0.011 at low tide on May 19, 2011 (Table 15). Upward head potentials were consistently higher at low tide level than at high tide.

Deep Zone of the Upper Glacial Aquifer and Jameco Aquifer

Upward head potentials were observed in the two well pairs (FW-MW-23 D1/D2 and GCMW-30D1/D2) installed in the deep zone of the Upper Glacial Aquifer and the Jameco Aquifer. Upward head potentials were observed at both high and low tide levels. The upward head potentials ranged between 0.08 and 0.042 in the GCMW-30D1/D2 well pair during various gauging events and were 0.13 and 0.14 within the FW-MW-23D1/D2 well pair at high and low tide, respectively, during the May 19, 2011 gauging event (Table 15). During the most recent gauging on May 19, 2011, the upward head potentials in both well pair were 0.13 at high tide and 0.14 at low tide. This suggests that both wells are exhibiting similar hydraulic conditions and groundwater flows upward from the semi-confined Jameco into the Upper Glacial Aquifer.

4. Nature and Extent

This section of the report describes the physical and chemical nature and extent of impacts identified through implementation of the RI at the former Fulton MGP Site. The discussion of nature and extent is based upon interpretation of data and observations obtained during conduct of the remedial investigation. To the extent they are relevant, we have also integrated data and observations from the NYSDEC's Site Characterization, and from investigations of the Gowanus Canal performed by GEI and USEPA.

The nature and extent of physical impacts and chemical constituents related to the former MGP operation is affected by a number of factors including: the presence of former MGP structures, former MGP processes, geologic conditions, groundwater flow patterns and historical land use. These detailed physical observations (visual and odors) are provided on the boring and test pit logs included in Appendix E. These observations are also summarized on geologic cross sections A-A′, B-B′, and C-C′ in Figure 11 and cross-sections D-D′ and E-E′ in Figure 12. Figure 13 provides a summary of physical impacts observed between elevation 0 and -25 feet. Discussion of depth is relative to feet bgs. Discussion of elevation is relative to the NAVD88.

The following terminology and descriptions were used to describe the visual and olfactory observations recorded on the boring and test pit logs, and the same descriptors are used to discuss the observed conditions discussed in this report and summarized on the report figures. During field investigations GEI personnel recorded their observations without attempting to interpret the meaning.

- **Saturated:** the entirety of the pore space of the soil matrix for a given soil sample appears to be filled with a NAPL. The characteristics of the observed NAPL were used in the description (i.e., tar-saturated or petroleum-saturated).
- **Coated –** soil grains are coated with tar/free-phase liquid – there is not sufficient free-phase material present to saturate the pore spaces. The term "coated" was used in conjunction with modifiers such as light, moderate or heavy to indicate the degree of coating.
- **Blebs:** observed discrete blebs or pockets of NAPL within a soil sample. The majority of the soil matrix did not exhibit the presence of NAPL beyond these discrete blebs. The characteristics of the observed NAPL were used in the description (i.e., tar blebs or petroleum blebs).
- **Sheen:** iridescence was observed within a soil sample.

- **Stained:** the soil sample exhibited a discoloration not apparently associated with natural processes. The color of the observed stain was used and if the characteristics of the staining material were discernible, they were also noted (i.e., tar-stained or petroleum-stained).
- **Odor:** if an odor was observed, it was described based on its relative intensity and characteristics. Modifier terms such as strong, moderate, and faint were used to describe relative odor intensity. Descriptive terms such as tar-like or petroleum-like odors were also used.

These terms assist in characterizing the potential range of NAPL conditions and mobility in the subsurface, ranging from a residual/non-mobile state to NAPL-saturated materials which may indicate potential mobility.

Tables 12 and 13 summarize the detected laboratory analytical results for surface and subsurface-soil samples collected during the former Fulton MGP RI. Subsurface soil data generated as part of the KeySpan Gowanus Canal investigation and the USEPA's RI of the Gowanus Canal are provided in Tables 2 and 3, respectively.

In accordance with NYSDEC regulations, soil analytical results are compared to Title 6, Chapter 100, Part 700-705, Subpart 375-6 of the New York State Code of Rules and Regulations (6NYCRR Part 375) Unrestricted Use Soil Cleanup Objectives (SCOs) (NYSDEC, 2006). In the remaining report text, these standards are referred to as the Unrestricted Use SCOs. Soil analytical results are also compared with the Restricted Use Commercial SCOs (subparagraph 375-1.8(g)(2)(iii) of Part 375), [Commercial Use SCOs]. The Commercial Use SCOs are appropriate for evaluating the significance of Site impacts in an urban setting because they reflect the commercial/manufacturing zoning use of the former Fulton MGP Site and surrounding area. The Commercial Use SCOs apply to sites where the land use involves buying, selling or trading of merchandise or services. Parks and areas of passive recreational use, where there is limited potential for contacting soils, can be classified under the Commercial Use category under 6NYCRR Part 375 (NYSDEC, 2006).

Chemical concentrations are discussed in terms of individual compounds and groups of compounds that are typically associated with former MGP operations. Generally, contaminants are grouped as organic or inorganic. Organic compounds include BTEX and PAHs. The BTEX group consists of:

- Benzene, toluene, ethylbenzene, and xylene.

The PAH group includes:

2-Methylnaphthalene	Anthracene
Benzo(b)fluoranthene	Chrysene
Fluorene	Phenanthrene
Acenaphthene	Benz(a)anthracene
Benzo(g,h,i)perylene	Dibenz(a,h)anthracene
Indeno(1,2,3-cd)pyrene	Pyrene
Acenaphthylene	Benzo(a)pyrene
Benzo(k)fluoranthene	Fluoranthene
Naphthalene	

These organic compounds are found in a variety of petroleum-related products as well as MGP by-products. PAHs in particular are rather ubiquitous in the urban environment and are commonly associated with multiple urban sources such as: asphalt pavement run-off; combustion fall out; “heavier” fuel storage facilities for heating oil, diesel ranges (No. 2 through 4), and boiler fuels (e.g. No. 6 and bunker crude); and abraded tire particulates found along roadways and washed into waterways, as well as many other industrial sources.

The soils analyses indicated the presence of a number of artificial organic compounds that had not been synthesized and/or were not broadly used during the era of the MGP operation. Such compounds include chlorinated solvents, PCBs, and organochlorinated pesticides. Since these compounds did not exist and/or were not broadly used at the time of the MGP operations, the presence of these compounds is related to land use activities that post-date the operation of the former MGP.

Tables 12 and 13 provide the individual compound results, the sum of the detected concentrations of BTEX (Total BTEX), and the sum of the detected concentrations of PAHs (total PAHs). For estimated concentrations of individual compounds (“J” qualified), the estimated value was used to generate the total. Detected compounds are bold in the table. Concentrations in excess of the Unrestricted and Commercial Use SCOs have been highlighted.

Table 16 presents the typical background concentrations of metals for the Eastern United States (Shacklette and Boerngen, 1984). Table 17 presents a summary of background PAH concentrations in surface soils (Retec, 2007). These tables are useful in evaluating the concentrations of inorganic (i.e., metals and cyanide) and organic compounds present at the Site and study area.

Tables 3and 16 include the groundwater analytical results generated during the Fulton MGP RI and USEPA Gowanus Canal RI, respectively. The results are compared to the NYSAWQSs for a GA area. Exceedances of these criteria have been highlighted and bolded in the table. It should be noted that while the results are compared against the NYSDEC’s

GA standards per NYSDEC guidance, NYC provides potable water to Brooklyn and; therefore, potential exposures related to consumption of groundwater are not of concern for this Site.

Soil vapor, indoor, and outdoor ambient air results are provided in Table 14. At this time, there is no background comparison data for soil vapor. In commercial settings, NYSDOH suggests that indoor and outdoor ambient air results should be compared to criteria in USEPA *Building Assessment and Survey Evaluation* (BASE),conducted by USEPA in 2001 (NYSDOH, 2006). The USEPA BASE study assessed background VOC concentrations within indoor air in public and commercial office buildings. A comparison to this database is appropriate since office areas are part of the current building operations on Parcels I, III, and V. USEPA RI ambient outdoor air data is provided in Table 5. Concentrations of compounds detected in air above the 90th percentile of the USEPA BASE Study levels are shaded in gray in Tables 5 and 14.

NYSDOH has established air guideline values for five non-MGP- related compounds [trichloroethene (TCE), tetrachloroethene (PCE), methylene chloride, PCBs and tetrachlorodibenzo-p-dioxin]. Methylene chloride, TCE, and PCE were detected in soil vapor and indoor air during the RI. Concentrations of compounds detected above the air guideline values are shaded in yellow in Table 14.

The NYSDOH Guidance for Evaluating SVI (October 2006) includes soil vapor/indoor air decision matrices developed to address situations where soil vapor may be entering a building. The NYSDOH has developed decision matrices for several compounds including TCE (Table 1 in Appendix H) and PCE (Table 2 in Appendix H). Based upon the findings and conditions, the guidance recommends five actions: 1. no further action, 2. identify and reduce exposures, 3. monitoring, 4. mitigation, and 5. mitigation/monitoring.

Tables 18 through 23 provide a statistical summary of detections by media.

4.1 Soil

The Site and RI study area have been subject to historical filling as part of the development of the area. Soils that contain fill can often contain elevated concentrations of compounds such as PAHs and metals.

The nature and extent of Surface Soil impacts is first discussed below and the discussion is organized by Parcel where the samples were collected. Next, Subsurface Soil nature and extent is discussed on a parcel-by-parcel basis. The reader is encouraged to refer to the cross sections (Figures 11 and 12) while reviewing the narrative of subsurface nature and extent.

For each Parcel discussion, the observed physical observations (visual and odor) are discussed followed by a discussion of the nature and extent of chemical impacts.
Fate and transport of the soil impacts are discussed in Section 5, and Section 6 presents a physical conceptual site model.

4.1.1 Surface Soils

Surface soils were collected within the footprint of and adjacent to the former Fulton MGP Site. The surface soils samples were collected from unpaved areas of Parcel I, Parcel II, Parcel IV, Parcel VI, and from exposed soils in tree planters within the Degraw and Sackett Street ROWs (Figures 2 and 3). No free-phase tar or petroleum impacts were observed within surface soils.

Laboratory testing results indicated that VOCs, SVOCs, pesticides, herbicides, PCBs, metals and cyanide (free and total) were detected in surface soils (Table 11). The presence of pesticides, herbicides, and PCBs are not associated with the former operation of the MGP and likely represent impacts associated with land uses post-dating the MGP operation. Only concentrations of PAHs were detected above the Commercial SCOs. The highest total PAH concentration (162.8 mg/kg) was detected within FW-SS-08 at Parcel II. As discussed below, the PAHs detected in this sample are likely related to fill materials.

A summary of surface soil analytical testing results by parcel is provided below.

Parcel I

One surface soil sample (FW-SS-06) was collected at Parcel I. The sample had a total BTEX concentration of 0.0093 mg/kg and total PAHs concentration of 8.724 mg/kg. Free cyanide was not detected in the sample. Two PAH compounds, PCBs, pesticides, and metals were detected at concentrations that exceeded the Unrestricted Use SCOs. However, all concentrations were below the Commercial Use SCOs. The presence of PCBs and pesticides are related to land uses that post-date the operation of the MGP.

Parcel II

Surface soil is exposed within tree planters in Thomas Greene Playground. The remainder of the park is asphalt paved. Three surface soil samples (FW-SS-05, FW-SS-08, and FW-SS-09) were collected from the exposed soil in the tree planters. BTEX concentrations in the samples ranged from 0.0012 to 0.0371 mg/kg and total PAH concentrations ranged from 16.19 to 162.8 mg/kg. Free cyanide was not detected in the surface soil samples. Total cyanide was detected at concentrations well below the Unrestricted Use SCOs (Table 11).

Pesticides and metals were detected at concentrations exceeding the Unrestricted Use SCOs. The presence of pesticides is related to land uses that post-date the operation of the MGP. PAH compounds were detected at concentrations above the Commercial Use SCOs. The PAH concentrations in FW-SS-05 and FW-SS-09 were, however, generally within ranges of typical background surface soils in NYC (Retec, 2007) (Table 11 and 17). FW-SS-08, located outside the footprint of the MGP gas production operations within the pipe laydown area, contained concentrations of PAHs above the Commercial Use SCOs and background PAH concentrations (Table 11). These surface soils likely consist of historic fill material; fill was encountered in deeper intervals at boring locations within the Park than at other parcels.

Parcel IV

Three surface soil samples (FW-SS-01 through FW-SS-03) were collected from Parcel IV. BTEX compounds were only detected in one sample (FW-SS-02) at a concentration of 0.0192 mg/kg at concentrations less than the Unrestricted Use SCOs. Total PAH concentrations ranged from 5.048 mg/kg to 11.2 mg/kg.

All three samples contained concentrations of PAHs, PCBs, pesticides, and metals at levels that exceed the Unrestricted Use SCOs. The presence of PCBs and pesticides are related to land uses that post-date the operation of the MGP. Only one PAH compound, benzo(a)pyrene (BAP), was detected at 1.4 mg/kg, which is above the Commercial Use SCO of 1 mg/kg (Table 11). This concentration falls within the range of background concentrations for surface soils in NYC.

Free cyanide and herbicides were not detected in surface soils at Parcel IV.

Parcel VI

Three surface soil samples (FW-DSS-01 through FW-DSS-03) were collected at the parcel. BTEX compounds and free cyanide were not detected in any of the three samples.

Total PAH concentrations ranged from 6.348 mg/kg to 23.98 mg/kg. SVOCs (including PAHs), pesticides, and metals were detected at concentrations that exceed the Unrestricted Use SCOs. The presence of pesticides is related to land uses that post-date the operation of the MGP. Only one PAH compound, BAP, was detected at a concentration (2.1 mg/kg) above the Commercial Use SCO in FW-DSS-03 (Table 11).

This parcel is located off-site of the former Fulton MGP footprint and the impacts are likely associated with urban fill and the long commercial history of the property.

Surrounding Properties

Two surface soil samples (FW-SS-04 and FW-SS-07) were collected within tree wells along the Degraw and Sackett Street ROWs.

BTEX concentrations were non-detected and 0.0166 mg/kg and total PAH concentrations were 6.087 mg/kg and 19.44 mg/kg.
PAHs, pesticides, total PCBs and/or metal compounds were detected at concentrations that exceed the Unrestricted Use SCOs in both samples. The presence of PCBs and pesticides are related to land uses that post-date the operation of the MGP. Only one PAH compound, BAP, was detected in FW-SS-04 at concentration (1.9 mg/kg) above the Commercial Use SCO (Table 11). This concentration was within the range of detections within background surface soils in NYC.

FW-SS-04 had a detection of total cyanide (0.062 mg/kg) and FW-SS-07 had an estimated concentration of free cyanide (0.0466 mg/kg). Both concentrations were below the Unrestricted Use SCOs.

4.1.2 Subsurface Soils

Subsurface soils are discussed by RI Parcel and by the following groupings:

- Shallow Subsurface Soil – The top 5-feet of soil that could easily be excavated during utility or construction activities.
- Deep Subsurface Soil – Subsurface soils deeper than 5 feet, where tar and petroleum physical impacts were observed. These impacts range as deep as 124 feet bgs, at Parcel VI. Soil samples for laboratory analysis were collected beneath observed impacted zones to depths of up to 140 feet bgs and serve to document the chemical findings beneath the observed physical impacts.

4.1.2.1 Parcel I

Parcel I is located adjacent to the Gowanus Canal between Degraw Street to the north and Sackett Street to the south. Former MGP structures at Parcel I included a generator house, retort house, condenser, and engine houses, a 100,000-gallon oil/naphtha tank, gasoline house, an aboveground tar separator on a trestle, underground tar/oil tanks with overflow pipes, an oil press room, an oil pump room, and a coal shed. Four underground storage tanks were also present on the Parcel. As discussed above in section 1.4, NYSDEC records indicated that they were closed in place or otherwise properly removed.

Twenty-six soil borings including off-set borings to install monitoring wells and off-set borings due to shallow refusals were drilled on Parcel I to assess the subsurface conditions. Seven soil borings (FW-SB-01 through FW-SB-05, FW-SB-05A, and FW-SB-05B) were completed inside the northwest portion of the warehouse building to characterize subsurface conditions associated with the former structures. The remaining portions of the building were occupied at the time of the RI and could not be accessed. To complete the assessment of the parcel soil borings were drilled around the outside of the warehouse. The following table identifies all the soil borings and monitoring wells installed to assess Parcel I.

Parcel I Soil Borings and Wells		
Soil Borings	**Soil Borings**	**Monitoring Wells**
FW-SB-01	FW-MW-03	FW-MW-01-Well
FW-SB-02	FW-MW-3R	FW-MW-1R-Well
FW-SB-03	FW-SB-06	FW-MW-02-Well
FW-SB-04	FW-SB-07/FW-MW-17	FW-MW-3R-Well
FW-SB-05	FW-SB-08	GCMW-30I
FW-SB-05A	FW-SB-27	GCMW-30D1
FW-SB-05B	KSF-SB-23	GCMW-30D2
FW-MW-01	KSF-SB-24	FW-MW-17
FW-MW-1R	KSF-SB-25	FW-MW-02
	KSF-SB-26	

During the RI, the Parcel I tenant renovated the building. Eight excavations [B-2, B-4 (north), B-4 (south), D-2, D-4, electrical, bathroom, and sink trench] were completed inside the warehouse to enhance footings and install utilities. These renovation excavations were completed to depths ranging between 0.5 feet to 6.2 feet bgs.

GEI observed the work on behalf of National Grid and provided oversight and on-site coordination during excavation and soil handling activities. Relevant observations are provided below. GEI's report of oversight activities *Excavation Oversight Summary Report, 270 Nevins Street, Fulton Municipal Works Former MGP Site, Brooklyn New York.* is provided in Appendix I.

Shallow Subsurface Soil

Fill materials were encountered within the top 5 feet at soil borings and excavations. Concrete and brick foundation materials, probably associated with the former condenser house, were encountered at borings FW-SB-05 and FW-SB-05A. Probable MGP building foundations for the gasoline house and engine houses were observed during excavations completed in the southeast and eastern portion of the warehouse.

No evidence of environmental impacts (visual or odors) was observed within the top 5 feet of soil in the borings and six of the eight excavations. Soils from the B-2 excavation (near former tar oil tanks) exhibited staining and slight to moderate diesel-like odors above the existing footing and staining and slight to moderate coal tar-like odors below the footing (3.5 feet to 6.2 feet bgs). Stained soils were observed at approximately 2.3 feet bgs in the bathroom excavation next to an abandoned 5,000–gallon fuel oil UST and within the former generator house.

BTEX concentrations ranged from not detected in a number of samples to 0.0382 mg/kg in FW-SB-02 (2 to 4 feet). None of the BTEX concentrations exceeded the Unrestricted Use SCOs.

Total PAH concentrations ranged from not detected to 474.4 mg/kg in FW-SB-03 (2 to 5 feet). Concentrations of acetone (a VOC), SVOCs (including PAHs), pesticides and metals were detected above the Unrestricted Use SCOs. The presence of pesticides is related to land uses that post-date the operation of the MGP. PAHs and two metal compounds (arsenic and mercury) were present at concentrations above the Commercial Use SCOs.

Free cyanide was detected in two samples, FW-MW-02 [3 to 4 feet] and FW-SB-06 [3 to 4 feet] at concentrations below the Unrestricted Use SCOs.

Deep Subsurface Soils

Fill and former foundations were encountered beneath the building slab and beneath the parking lot area to a maximum depth of 15 feet bgs [approximately elevation 0 to -2 feet]. The shallowest observable impacts on and around Parcel I were petroleum odors (diesel like odors) and sheen identified as shallow as approximately 5 feet bgs beneath the warehouse building. Most petroleum-related observed impacts were found coincident or near the water table at approximately 8 feet bgs or deeper. Petroleum (diesel)-like odors and staining were observed to as deep as 32 feet bgs [elevation -22.16 feet] in FW-SB-01 (Cross-section B-B′ [Figure 11] and Cross-section D-D′ [Figure 12]).

With one exception (FW-SB-27 in the Degraw Street ROW) tar-related soil impacts were observed at depths of 10 feet bgs or greater. Tar sheen and isolated blebs of tar were observed as shallow as 5 feet in FW-SB-27. Only tar coated soil grains, sheen, and tar-stained soils were observed on Parcel I with the exception of tar saturated lenses in GC-GP-06 (41.75 to 45 feet bgs), FW-SB-04 (coatings from 27.5 to 45 feet bgs, and saturated lenses between 42.5 to 42.75 and 45.5 to 45.75 feet bgs) and FW-SB-06 (tar lens at 24 feet bgs; tar coatings 40 to 45 feet bgs). The deepest tar-related impact observed was a moderate naphthalene odor at 105 feet bgs in GC-MW30D2.

In soils with physical impacts and odors, BTEX concentrations ranged from not detected in a number of samples to 52.0 mg/kg in FW-SB-04 (42 to 43 feet) and total PAH concentrations ranged from not detected to 5,041 mg/kg in FW-SB-03 (8 to 10 feet). Cyanide was not detected in any sample (Table 3 and Table 12).

Concentrations of VOCs (BTEX, acetone and chlorinated VOCs), PAHs, pesticides, and metals (arsenic, mercury, nickel, and zinc) were present at levels above the Unrestricted Use SCOs. Chlorinated VOCs and pesticide concentrations are unrelated to the operation of the former MGP and represent impacts associated with land uses post-dating the MGP presence. Benzene in one sample (FW-SB-04 [42 to 43 feet bgs) and PAH compounds in a number of samples were present at concentrations above the Commercial Use SCOs (Table 3 and Table 12).
Ten soil samples were collected beneath visually observed impacts in eleven soil borings: FW-MW-02, FW-MW-03, GCMW-30D2, and FW-SB-01 through FW-SB-08. The samples were collected between 45 and 151 feet bgs. All concentrations with the exception of nickel and acetone were present at levels below the Unrestricted Use SCOs in the soil samples. Concentrations of nickel and acetone were present at levels below the Commercial Use SCOs (Table 3 and Table 12). These results document that the vertical extent of MGP-related impacts has been bounded for these boring locations.

The most widespread subsurface impacts in Parcel I are shallow and petroleum-related, with diesel and petroleum odors to maximum depths of about 25 feet bgs; saturation with petroleum-related NAPL was not uncommon. Tar-related impacts are more common beginning at about 20 feet bgs and extending deeper. FW-SB-06 at 24 feet bgs; a tar coating was observed at FW-SB-06 between 92 and 98 feet bgs. This deep interval provides a measure of how DNAPL has migrated in the past.

Physical Impacts

The table below presents a summary of physical impacts more significant than odor and staining at Parcel I.

Boring ID	Depth Intervals (ft bgs)	Physical Impact Observations
FW-SB-02	30-35	Tar coated
FW-SB-03	15-20 20-21	Petroleum coated Tar coated
FW-SB-04	10-20 22.5-25, 27.5-42.5, 42.7-45 42.5-42.7, 45.5-45.75	Petroleum sheen Tar coated Tar saturated
FW-SB-05/05A/05B	10-25, 30-30.5	Tar coated
FW-SB-06	20-25, 92-98	Tar coated
FW-SB-07/FW-MW-17	28-35, 44.5-45	Tar coated
FW-SB-08	28.3-30, 33.3-35 37.1-37.3, 60-65	Tar coated Tar lenses
FW-SB-27	5-10	Tar blebs
KSF-SB-24	13-16	NAPL
FW-MW-01	15-25 65-66	Petroleum sheen Tar lenses
FW-MW-03	25-29.3	Petroleum sheen

Boring ID	Depth Intervals (ft bgs)	Physical Impact Observations
GCMW-30I/D2	23.5-26, 27-28	Tar sheen
GC-GP-06	7.75-12	Petroleum sheen
	12-17	Petroleum sheen to coated
	17-17.5	Petroleum coated/saturated
	17.5-27.75	Petroleum sheen to coated
	27.75 - 28.75	Petroleum sheen
	38.8 – 39	Tar saturated
	41.75 - 45	Tar saturated lenses

These observations demonstrate that the subsurface at Parcel I is impacted by both petroleum and tar.

Gowanus Canal Adjacent to Parcel I

Eight sediment cores were collected in the Gowanus Canal adjacent to Parcel I. The table below presents a summary of physical impacts more significant than odor and staining.

Boring ID (elevation - ft NAVD88)	Depth Interval (ft below mudline)	Physical Impact Observations (elevation of tar impacts - ft NAVD88)
ERT 3-1	0-1	Petroleum sheen
GC-SED108 (-4.2)	0-12.8 12.8-13.5	None observed Tar coatings and Saturation
GC-SED-07 (7.05)	13-18	Petroleum coated
GC-SED-08 (-4.87)	9.5-10 10-10.5 10.5-20	Petroleum saturated lenses Petroleum and tar blebs (-14.87) Tar coated
GC-SED-09B (-3.53)	0-2, 7-10.5 6-7, 15.2-20* 12-13	Petroleum sheen Tar coated (-9.53, -18.73) Petroleum coated
GC-SD152 (-3.5)	6-7.3, 7.7-9.7	Petroleum coated

*Depth interval includes lenses of NAPL observation. Elevations for ERT borings are not available.

The sediment surface elevation at GC-SD108 is -4.2 feet NAVD88, and tar impacts were observed at elevation -17. The closest soil boring in Parcel I is FW-SB-05B. Tar coatings were present in this soil boring from elevation 3.01 to elevation-11.99. The higher elevation of tar on the landside relative to tar impacts in the canal suggests there may have been migration into the sediments.

The closest landside boring to GC-SED-09B is GC-GP-06. The elevation of the first tar-related impacts in GC-GP-06 was -29.34. Tar impacts in GC-SED-09B were at -9.53, significantly shallower. These data suggest that some tar may have migrated toward the landside. The same relationship is apparent between GC-SED-08 and GC-GP-06.

4.1.2.2 Parcel II

Parcel II was used for petroleum storage and manufactured gas storage for the MGP operations along the southern portion of the parcel. A wagon house/garage occupied the eastern portion of parcel adjacent to 3rd Avenue. The northern portion of the parcel appears to have been used primarily for gas piping lay-down/support area. Unidentified storage tanks were present on the northwestern portion of the Parcel.

The discussion of soil findings below is organized by the two areas of Thomas Greene Playground, the playground area and the pool/handball court areas

Playground Area

The following investigations were completed in the Playground Area to evaluate the former gas oil/naptha tanks and the 500,000-gallon oil tank locations, to confirm the extent of the impacts encountered in the NYSDEC's SC borings, and to define the lateral extent of tar impacts.

- Seventeen soil borings:
  - KSF-SB-09 through KSF-SB-13
  - FW-SB-17/A/B, FW-SB-18, FW-SB-19, FW-SB-21, FW-SB-23, FW-MW-16 boring/well, FW-MW-07 boring/well, and FW-MW-06
  - GC-MW32I/GC-MW32IR
- Five test pits: (FW-TP-04 through FW-TP-08)

Six borings were installed in the Douglass and Degraw Street ROWs or sidewalks to evaluate the extent of tar impacts to the northwest of the parcel.

- Degraw Street ROW: KSF-SB-15/MW-5 and FW-MW-5R
- Douglass Street ROW: FW-SB-08,FW-MW-08,FW-SB-36, and FW-SB-39

Shallow Subsurface Soil

Fill was encountered within shallow subsurface soils at each soil boring and test pit location. Test pit excavations (FW-TP-07 and FW-TP-08) encountered a concrete foundation wall of the former gas oil/naptha tank (Tanks No. 2 and 4) at approximately 4.5 feet bgs [elevation 10.48 feet].

Petroleum (diesel-like) odors were observed as shallow as 1 to 5 feet bgs at FW-MW-06. Other petroleum-related impacts were not observed in the top 5 feet of soils in this area. No tar-related impacts (visual or odor) were observed.

BTEX concentrations in samples collected in the interval ranged between not detected in a number of samples to 0.0061 mg/kg in FW-SB-19 (1 to 5 feet). But no BTEX concentrations exceeded the Unrestricted Use SCOs. Total PAH concentrations ranged from 0.655 mg/kg in FW-SB-36 (0.5 to 5 feet) [Douglass Street ROW] to 368.7 mg/kg at FW-MW-08 (4 to 4.5 feet) in the Douglass Street ROW. Concentrations of individual PAHs and metals (arsenic, barium, copper, lead, mercury, nickel, and zinc) were present above the Unrestricted Use SCOs. Some PAHs and metal compounds (arsenic, barium, copper, lead, and mercury) concentrations also exceeded the Commercial Use SCOs.

Total cyanide was detected in seven samples at concentrations that ranged from an estimated detection of 0.1 mg/kg to 3 mg/kg. The concentrations were below the Unrestricted Use SCOs. Free cyanide was not detected in shallow subsurface soils (Tables 3 and 13).

As of March 2012, the NYC Department of Parks and Recreation had begun planning/implementing improvements to the playground area in the eastern portion of Parcel II. NYSDEC advised City personnel that no remediation is first required in this area. The surface soil quality is within “urban background” conditions (subsection 4.1.1 Parcel II) and shallow subsurface impacts are relatively minor.

Deep Subsurface Soils

The soil borings completed within the footprint of the former gas oil/naphtha tanks encountered fill to a depth of approximately 22.5 feet bgs [elevation -3.5 feet], coinciding with the bottom of the tanks.

Soil borings (FW-SB-17, FW-SB-17A, and KSF-SB-12) encountered refusal between approximately 16.5 and 18 feet bgs [elevation 2.15 and 0 feet] within the footprint of the former 500,000-gallon oil tank (Cross-section D-D', Figure 12); the floor of the oil tank likely corresponds to this depth. Concrete fragments were encountered in FW-SB-17 and test pit, FW-TP-05, which are likely associated with the foundation wall for the oil tank. The fill revealed by these explorations illustrate that the tank pit was filled with soil that included concrete debris, coal fragments, brick, and wood.

Outside the former fuel oil tank foundations, fill materials were encountered as deep as 24 feet in FW-SB-17B on the south side of the playground and in KSF-SB-11 in the northern portion of the playground.

Below 5 feet, soils with staining and sheens that exhibited petroleum and diesel-like odors were encountered between approximately 5 and 20 feet bgs [elevation 6.9 and -1.45 feet] in multiple soil borings (KSF-SB-09 through KSF-SB-13, FW-SB-17/A/B, FW-SB-18, FW-SB-19, FW-SB-21, FW-SB-23, and FW-MW-08), and test pits (FW-TP-04 and FW-TP-05).

The shallowest tar-related impacts were encountered in test pitFW-TP-06, where tar blebs, tar-coated soil, and staining were observed at 11 to 12 feet bgs, within the former 500,000-gallon oil tank. Tar-coated to tar-saturated soils were observed in test pit FW-TP-07 (12.5 to 13.2 feet bgs) within the footprint of the gas oil naphtha tanks.

Intervals of tar-stained to tar-coated soils were encountered primarily between 20 and 60 feet bgs [elevation -1.73 to -42.35 feet] in all the borings in the playground area with the exception of FW-SB-17B, FW-MW-06 and FW-MW-07 and KSF-SB-11. Cross-section D-D' and E-E' (Figure 12) depict the extent of the impacts in the Playground Area.
Within soils exhibiting physical tar-related impacts, BTEX concentrations ranged from not detected in a number of samples to a maximum concentration of 2,840 mg/kg in FW-SB-23 (40 to 41 feet) and total PAH concentrations ranged from not detected to 26,460 mg/kg SB-23 (40 to 41 feet).

Total cyanide was detected in three samples with a maximum concentration of 1.6 mg/kg at GC-MW32I (5 to 10 feet), at levels well below the Unrestricted Use SCOs. Free cyanide was not detected (Tables 3 and 13).

VOCs (BTEX and acetone), SVOCs (PAHs and dibenzofuran), 4,4-DDD (pesticide), and metals (arsenic, barium, copper, lead, mercury, nickel and zinc) were detected at concentrations that exceed the Unrestricted SCOs. The presence of 4,4-DDD is related to land uses that post-date the operation of the MGP. BTEX compounds, PAHs, and metals (arsenic, barium, lead and mercury) were detected at concentrations that exceeded the Commercial Use SCOs.

Eleven soil samples were collected beneath the observed tar-related impacts from eleven soil borings: FW-MW-06 through FW-MW-08, FW-MW-16, FW-SB-21, FW-SB-23A, FW-SB-36 and FW-SB-39, and FW-SB-17B through FW-SB-19. The samples were collected between 50 and 100 feet bgs. All concentrations were below the Unrestricted Use SCOs in the samples (Table 3 and Table 12). These findings bound the vertical extent of MGP-related impacts beneath the playground area.

Pool and Handball Court Areas

The following soil borings were completed in the Pool/Handball Court Area:

- KSF-SB-01 through KSF-SB-08
- FW-SB-20, FW-SB-22, FW-SB-24 through FW-SB-26, and FW-SB-30 through FW-SB-32

This area of the Fulton MGP previously contained a hydrogen tank (gas holder), two oil tanks (tank No. 7 and No. 8), portions of gas oil tanks (No. 1 to No. 6), and unidentified tanks.

Six borings installed within the Douglass and Degraw Street ROWs are also discussed in this section:

- Degraw Street ROW: KSF-SB-16 through KSF-SB-18)
- Douglass Street ROW: FW-SB-28, FW-MW-09, and FW-MW-09-Well)

The borings completed in Douglass Street were installed to confirm the extent of the impacts encountered in the NYSDEC's SC borings, and to define the lateral extent of tar impacts.

Shallow Subsurface Soil

Soils within the top 5 feet consist of fill used to raise the ground elevation for the pool area above the existing grade of the street. The fill included brick, cobbles, glass, metal fragments, coal, ash, cinders, concrete, and asphalt. Petroleum odor and/or staining were observed in FW-SB-21, FW-SB-22, FW-SB-24, FW-SB-25, FW-SB-28, KSF-SB-05 and KSF-SB-07. Observable tar-related impacts (visual and odor) were not observed in the top 5 feet of soils in this area.

BTEX concentrations in samples collected in the top 5 feet ranged from not detected in a number of samples to 0.1042 mg/kg in FW-SB-24 (0.5 to 5 feet). BTEX concentrations were at levels below the Unrestricted SCOs. Total PAH concentrations ranged from 3.167 mg/kg in FW-SB-30 (1.3 to 5 feet) to 803.9 mg/kg in FW-SB-24 (0.5 to 5 feet). Concentrations of VOCs (methylene chloride and acetone), individual PAHs, total PCBs, pesticides, and metals (copper, lead, mercury, and zinc) were present above the Unrestricted Use SCOs. The presence of PCBs and pesticides is related to land uses that post-date the operation of the MGP. Individual PAH concentrations were present above the Commercial Use SCOs. Total cyanide was detected in five samples ranging from an estimated detection of 0.16 mg/kg to 7.1 mg/kg, at levels below the Unrestricted Use (27 mg/kg) SCO. Free cyanide was not detected in any sample.

Deep Subsurface Soils

Below 5 feet, soils with staining and sheens that exhibited petroleum and diesel-like odors were encountered between approximately 5 and 12.5 feet [elevation 8.7 to 1.14 feet] in soil borings (FW-MW-09, FW-SB-22, FW-SB-25, FW-SB-28, FW-SB-30, and FW-SB-31) and SC borings (KSF-SB-03, KSF-SB-04, KSF-SB-07, KSF-SB-08, and KSF-SB-16).

The shallowest tar-related impacts (tar-like odor and tar-stained soils) were observed starting at 5 feet bgs [elevation 8.78 feet] in FW-SB-26. Tar-coated soil grains were observed as shallow as 10 feet bgs in this area with tar-saturated soil observed in FW-SB-24 (10 to 15 feet bgs) and tar saturated lenses observed in FW-SB-25 from 10 to 20 feet bgs. The deepest tar-related impacts in this area were tar-coated soil observed at 105 feet bgs [elevation -91.22 feet] in FW-SB-25. The extent of observed impacts are shown in Cross-section A-A' in Figure 11.

In soils with observed visual impacts and odors, BTEX concentrations ranged from not detected to 5,280 mg/kg in FW-MW-09 (58 to 60 feet) and total PAH concentrations ranged from not detected in several samples to 39,090 mg/kg at FW-SB-26 (42 to 43 feet). Total cyanide was not detected in samples. Concentrations of BTEX, SVOCs (PAHs and dibenzofuran), and metals (arsenic, lead, mercury, nickel, selenium, and zinc) were detected at levels above the Unrestricted SCOs. Concentrations of BTEX, PAH compounds and metals (arsenic and mercury) were present at concentrations above the Commercial Use SCOs (Table 12).

Seven soil samples were collected beneath the observed tar-related impacts in seven soil borings: FW-SB-20, FW-SB-22, FW-SB-24, FW-SB-30 and FW-SB-31 within the pool area and FW-MW-09 and FW-SB-28 within the Douglass Street ROW. The samples were collected between 70 and 80 feet bgs (Table 12 and Figure 3). All concentrations were present at levels below the Unrestricted Use SCOs in soil samples collected beneath the impacted soils. These data bound the vertical extent of tar-related impacts in this area.

Physical Impacts

The table below presents a summary of physical impacts more significant than odor and staining at Parcel II.

Boring ID	Depth Intervals (ft bgs)	Physical Impact Observations
FW-SB-17B	17-20	Petroleum coated
FW-SB-18	15-17 48-48.5 56-60	Petroleum blebs and globs Tar lenses Tar sheen
FW-SB-19	9-10, 16-17 20-24, 40-41.5, 42-45 38.5-40, 41.5-42	Petroleum sheen Tar blebs and globs Tar coated
FW-SB-20	13.75-14.75, 28.5-34, 35-35.3, 39.8-40 15-16 16-19.2 34-35	Tar coated Tar blebs Tar blebs and coating Tar saturated
FW-SB-21	12.5-15 20-22, 34-37.5, 38-38.5 22-22.5	Petroleum sheen Tar coated Tar saturated
FW-SB-22	10-20, 28-32 20-25, 36-40 65-70	Tar coated Tar sheen Tar lenses

Boring ID	Depth Intervals (ft bgs)	Physical Impact Observations
FW-SB-23	20-21.5 39-42	Tar blebs and globs Tar coated
FW-SB-24	0.5-5 10-15, 35-36 15-17.5, 33-34*, 36-37, 44.5-45 31-33	Petroleum sheen Tar saturated Tar coated Tar sheen
FW-SB-25	7-7.5 10-20*, 33-40*, 40-45*, 45-45.7, 64-65, 75-76.5 45.7-47, 76.5-85, 97.5-100 50-60*, 65-70*, 89-90, 95-97.5, 100-105	Petroleum saturated Tar saturated Tar sheen Tar coated
FW-SB-26	15-16*, 27-30, 33-35*, 45-54* 35-45*, 54-62.5*	Tar coated Tar saturated
FW-SB-28	10-12, 33-37 31.5-33*, 37-40*, 60-61.5, 64.9-65 40-40.2, 51-54*, 59.9-60 54-55, 61.5-63.5	Tar blebs Tar saturated Tar coated Tar sheen
FW-SB-30	16-16.5, 32.8-35*, 45-45.4, 59.3-60, 64.9-65 27-30* 60-62	Tar coated Tar sheen Tar saturated
FW-SB-31	14.75-20.3, 28-30, 33.5-35, 36.4-37.8, 40-50* 30-32.5 50-50.8	Tar coated Tar sheen Tar saturated
FW-SB-32	10-15, 25-29.4, 30-35, 39-39.5, 40-44.2 35-39, 96.5-97.5 97.5-100	Tar coated Tar coated with saturated lenses Tar sheen
FW-MW-08	34.5-35.1, 48.5-48.6	Tar coated
FW-MW-16	46.5-47.5, 52-55 50-52	Tar coated Tar sheen
GCMW-32I	42-46	Tar coated

* Depth interval includes lenses of NAPL observation.

The observations summarize the different types of impacts at Parcel II. Tar-related impacts are most prevalent, and are present as deep as 105 feet bgs. None of the borings have continuous impacts from ground surface to termination depth; in the vertical plane most impacts are discontinuous, but there is general downward trend in the impacts - the farther from the Site, the deeper impacts are observed. We cannot determine if there is current mobility, because there is no way to directly observe such behavior. However, mobility can be associated with saturated intervals and it is possible that DNAPL from Parcel II has contributed to impacts at Parcels I, III, and VI.

As of March 2012, the NYC Department of Parks and Recreation had begun planning/implementing improvements to the playground area in the eastern portion of Parcel II. NYSDEC advised City personnel that no remediation is first required in this area. The surface soil quality is within “urban background” conditions (subsection 4.1.1 Parcel II) and shallow subsurface impacts are relatively minor.

4.1.2.3 Parcel III

This area of the MGP was used for gas purification and storage. Former structures include two purifying houses, four oxidizing sheds, scrubbers, a governor house, a gas holder, a portion of a second gas holder and coal storage. The area now contains a book warehouse that covers almost the entire parcel. As a result, access was difficult and the possibility of advancing step-out borings was limited. Four soil borings (FW-SB-11 through FW-SB-13/13A, and FW-SB-16) were completed to evaluate subsurface soils within and adjacent to the footprint of the former MGP gas holders.

Seven soil borings FW-SB-09, FW-SB-10, FW-SB-11A, FW-MW-04, KSF-SB-21/MW-7, KSF-SB-22, and KSF-SB-28) were completed adjacent to Parcel III within the Degraw, Nevins, and Sackett Street ROWs.

Shallow Subsurface Soil

Soils beneath Parcel III contained fill materials including: brick and concrete fragments, pieces of rubber, metal wire, and coal fragments.

Tar sheen was observed in the top 5 feet of fill as shallow as 3.7 feet bgs [elevation 7.86 feet] in FW-SB-12 located within the footprint of the former holder. Outside the former holder, petroleum odors and staining were encountered in FW-SB-10 between 2 and 4 feet bgs [elevation 6.59 feet and 4.59 feet] beneath the Degraw Street ROW and NYSDEC noted diesel odors at 4.0 to 6.5 feet bgs in KSF-SB-22 at the same location as FW-SB-10.

BTEX ranged in concentration from not detected in a number of locations to 0.0896 mg/kg in FW-SB-12 (3.5 to 4.5 feet). Total PAH concentrations ranged from 0.547 mg/kg in FW-SB-09 (0 to 2.0 feet) to 444.8 mg/kg in FW-SB-12 (3.5 to 4.5 feet). Concentrations of VOCs (benzene and PVC [a chlorinated VOC], PAH compounds, pesticides, PCBs, and metal compounds were detected at concentrations above the Unrestricted Use SCOs. The presence of chlorinated VOCs, PCBs, and pesticides is related to land uses that post-date the operation of the MGP. PAHs and metals (arsenic, barium, cadmium, copper, and lead) were detected at concentrations above the Commercial Use SCOs.

Deep Subsurface Soils

Backfill material within the holder consists of sand and gravel fill containing brick and concrete fragments. Within the footprint of the former gasholder, refusal was encountered in borings FW-SB-12 and FW-SB-13A at approximately 18 to 18.5 feet bgs [approximately elevation -6.44 to -7.2 feet], indicating the bottom of the gasholder. Fill materials (brick, concrete, and metal wire fragments) were observed within FW-SB-11 to a depth of 16 feet bgs [elevation 3.78 feet].

Tar-saturated soils were encountered within the former holder foundation as shallow as 5 to 11 feet bgs. Lenses of tar, sheen, tar-saturated layers and tar-coated soils were encountered from 5 feet [elevation 6.56 feet] to the bottom of the holder at approximately 18.5 feet bgs [elevation -7.2 feet].

The water level elevation measured in FW-SB-11, in the holder, was 8.04 feet. At well KSF-MW-7, outside the holder, the elevation varied from approximately 2.3 to 2.6 feet. At well FW-MW-03 (Parcel I) the elevation varied from 1.77 to 1.97 feet. These data demonstrate that the holder currently contains water at a level almost six feet higher than the natural groundwater table surrounding it. While impacts inside the holder are primarily tar-related, impacts outside the holder are generally shallower than 25 feet bgs and were petroleum-related.

BTEX concentrations ranged from 29 mg/kg in FW-SB-13 (6.5 to 8 feet) to 6,710 mg/kg in FW-SB-11 (15.0 to 15.75 feet) and total PAH concentrations ranged from 148.9 mg/kg in FW-SB-13A (17 to 18) to 22,099 mg/kg in FW-SB-11 (15 to 15.75 feet) immediately next to the holder.

Concentrations of VOCs (BTEX compounds, acetone, and chlorinated VOCs [cis-1,2-Dichloroethene, methylene chloride, TCE, and PVC]), SVOCs (including PAHs and dibenzofuran), and metals were detected above Unrestricted Use SCOs. The presence of chlorinated VOCs is related to land uses that post-date the operation of the former MGP. Individual BTEX compounds, PAHs, and copper were detected at concentrations above the Commercial Use SCOs.

Cyanide was only detected in two samples collected from FW-SB-11 at concentrations well below the Unrestricted Use SCOs (Table 12).

Outside the former holder, in FW-SB-11A along Nevins Street, petroleum impacts were encountered in intervals between 10 feet bgs [elevation 3.59 feet] and 15 feet bgs [elevation -1.45 feet]. Tar impacts were observed from 21 feet bgs to 27 feet bgs and between 31 and 34 feet bgs and between 47 and 50 feet bgs/ [elevation -41.45 feet].

Five soil samples were collected beneath the observed tar-related impacts in five soil borings: FW-SB-16 (in the parking lot area) and FW-SB-09, FW-SB-10, FW-SB-11A, and FW-MW-04 within the Degraw, Sackett, and Nevins Street ROWs. The samples were collected between 45 and 75 feet bgs (Table 12 and Figure 3). All concentrations in the samples were below the Unrestricted Use SCOs. These data bound the vertical extent of MGP-related impacts at this parcel.

Physical Impacts

The table below presents a summary of physical impacts more significant than odor and staining at Parcel III.

Boring ID	Depth Intervals (ft bgs)	Physical Impact Observations
FW-SB-09	29.5-30 30.8-31.9 31.9-35, 37.9-40 46.4-48.3	Petroleum coated Petroleum saturated lenses Petroleum sheen Tar coated
FW-SB-10	5-7.5 7.5-10, 10.5-13 10-10.5, 26-29 24-25, 30-35	Petroleum sheen Tar sheen Tar blebs with coated lenses Tar coated lenses
FW-SB-11 Inside the holder	8.6-9.3, 9.8-13.6, 15.7-16 13.6-15.7	Tar coated Tar saturated
FW-SB-11A	10-15 21-27.5 31-33.5 33.5-34	Petroleum sheen Tar sheen Tar blebs and globs Tar coated
FW-SB-12 Inside the holder	5-11 11-18	Tar coated to saturated Tar coated with saturated lenses
FW-SB-13/13A Inside the holder	6.5-13.4 13.4-14 14-18.5	Tar sheen Tar coated Tar blebs

Tar was observed outside the holder, specifically at borings FW-SB-10 and FW-SB-11A. Tar outside the holder is mostly found at depths of 25 feet bgs or deeper; shallower impacts outside the holder are generally petroleum related.

4.1.2.4 Parcel IV

This area of the MGP was used for gas and coal storage. Former structures include a portion of a gas holder and a coal shed. Four soil borings (FW-SB-14, FW-SB-15, FW-MW-05 boring and FW-MW-05-Well) were installed and three test pits (FW-TP-02A, FW-TP-02B and FW-TP-03) were excavated to investigate the potential for impacts within and adjacent to the footprint of a former MGP gas holder.

Two soil borings (KSF-SB-19 and KSF-SB-20) were completed adjacent to Parcel IV within the Degraw Street ROW.

Shallow Subsurface Soil

Test pit excavations uncovered the top of the former gas holder foundation at approximately 1 foot bgs. Sand with gravel and some brick and other fill material was used to backfill the holder foundation. Outside the former holder foundation, fill materials including brick, metal, glass, brick, coal, and ash were encountered in soil boring FW-MW-05, KSF-SB-19 and KSF-SB-20 in the Degraw Street ROW.

No observed tar or petroleum-related impacts were encountered in the upper 5 feet within or outside of the holder footprint. BTEX was not detected in the top 5 feet. Total PAH concentrations ranged from 13.79 mg/kg in FW-SB-14 (0 to 3 feet) to 65.43 mg/kg in FW-SB-15 (0 to 3 feet) which was located inside the holder foundation. PAHs, pesticides, PCBs and metals were present at concentrations that exceeded the Unrestricted Use SCOs. The presence of PCBs and pesticides is related to land uses that post-date the operation of the MGP. Free cyanide was detected in one sample FW-MW-05 (0 to 0.5 feet) at an estimated concentration of 0.0428 mg/kg, which is below the Unrestricted SCO. Only PAH compounds were present at concentrations above the Commercial Use SCOs (Table 12).

Deep Subsurface Soils

Soil borings FW-SB-14 and FW-SB-15 encountered refusal at approximately 19 feet bgs [elevation-3.05 feet] within the footprint of the former holder, which is assumed to be the base of the holder foundation. Outside the former holder foundation, fill materials including brick, metal and wood fragments was encountered to a depth of 15 feet bgs [elevation -2.94 feet] in soil boring FW-MW-05.

Tar-related impacts ranging from sheen to tar-saturated lenses were observed within the holder foundation between 13 feet [elevation ~0. feet] and at the suspected bottom of the holder foundation at 19 feet bgs [elevation -3.05 feet]. BTEX concentrations ranged from not detected in a number of samples to 2,390 mg/kg in FW-SB-15 (18.69 to 19 feet). Total PAH concentrations ranged from 4.097 mg/kg in FW-TP-03 (9 to 9.5 feet) to 7,099 mg/kg in FW-SB-14 (13.14 to 15 feet). Concentrations of BTEX compounds, SVOCs, and metal compounds were detected above the Unrestricted Use SCOs; however, only BTEX compounds (benzene, ethyl benzene and xylene) and individual PAH compounds exceeded the Commercial Use SCOs (Table 12).

Outside the holder foundation, tar-related impacts were not encountered at FW-MW-05, upgradient of the holder. However, soils with petroleum-related NAPL blebs and petroleum-like odors were encountered between 15 feet and 17.5 feet bgs [elevation 2.94 to 0.44 feet] just below the apparent groundwater surface. Petroleum-like odors were observed in this boring to a depth of 23 feet bgs. NYSDEC noted the observation of sheen, coal tar odor, and black stained soils between 8 and 16 feet bgs in boring KSF-SB-20. A soil sample analyzed from FW-MW-05 at 15-17.5 feet bgs contained a total BTEX concentration of 38 mg/kg and the total PAH concentration was 489.8 mg/kg.

Concentrations of BTEX, PAH, and metal compounds were detected above the Unrestricted Use SCOs in the sample. Only individual PAH values exceeded the Commercial Use SCOs.

Visual impacts were not observed in FW-MW-05 boring below 23 feet bgs, even though the boring was advanced to 50 feet bgs [elevation -32.06 feet]. At boring FW-SB-16, to the west of the holder on the boundary between Parcel IV and III, petroleum and tar odors were noted between 25 and 55 feet bgs. However, no other physical impacts were observed throughout its total depth of 75 feet.

A soil sample was collected for laboratory analysis at the termination depth of FW-MW-05 (49.5 to 50.0 feet bgs) beneath any observed impacts. BTEX compounds were not detected. Total PAHs were detected at 0.977 mg/kg. Concentrations of all detected compounds were well below the Unrestricted Use SCOs (Table 12). These results vertically bound the extent of MGP-related impacts at this location.

The condition of the holder is uncertain. Water levels both inside and outside of the foundation are roughly equal.

Physical Impacts

The table below presents a summary of soil boring physical impacts more significant than odor and staining at Parcel IV.

Boring ID	Depth Intervals (ft bgs)	Physical Impact Observations
FW-SB-14 Inside holder	13.1-13.8, 14.7-15 13.8-14.7 15-16.9	Tar coated Tar saturated lenses Tar sheen
FW-SB-15 Inside holder	16.5-17.3 17.3-18.6 18.6-19	Tar sheen Tar blebs Tar saturated lenses
FW-MW-05	15-17.5	Petroleum blebs

Materials in the holder foundation are heavily impacted by tar. Outside of the holder foundation, Parcel IV is relatively unaffected, with only petroleum and naphthalene odors being observed at borings FW-SB-16 and FW-MW-05.

4.1.2.5 Parcel V

This portion of the Site was used as a remote gas holder station. The parcel included a gas holder, two engine/blower rooms, four wells and a water tank. After 1934, the on-site building was constructed at the Parcel and used as a truck garage that utilized gasoline and diesel USTs.

Three soil borings (FW-SB-33, FW-SB-33A, and FW-SB-34) were completed within the footprint of the former gasholder at the parcel, and soil boring FW-SB-43 was completed outside the footprint of the holder. NAPL was not observed in any of the borings inside the holder. However, petroleum and naphthalene odors were detected.

Three additional soil borings (FW-MW-12, FW-MW-13, and FW-MW-14) were completed within the Degraw and Douglass Street and 3rd Avenue ROWs adjacent to Parcel V. Monitoring wells were installed in offset borings immediately adjacent to each of these three boreholes. NAPL was not observed in any of the borings outside the holder. However, petroleum odors were common.

Shallow Subsurface Soils

The upper 5 feet of soil on Parcel V consisted of sand to silty-sand with varying degrees of fill materials such as brick fragments. No evidence of petroleum or tar-related impacts was observed (visual or odors) in the upper 5 feet of soils in any boring on the parcel or in the adjoining ROWs. In the top 5 feet, BTEX ranged from not detected in multiple samples to 0.0017 mg/kg in FW-SB-33 (0.5 to 5 feet bgs). Total PAH concentrations ranged from not detected in FW-MW-13 (0 to 2 feet) to 210.97 mg/kg at FW-SB-43 (0.5 to 5 feet) within fill located upgradient, outside the footprint of the holder. Free cyanide was only detected in one sample (FW-SB-33 [0.5- 5.0 feet]) at a level below the Unrestricted Use SCO. Individual concentrations of acetone, PAHs, 4,4-DDT, and metals exceeded Unrestricted Use SCOs. Concentrations of individual PAHs and metals (arsenic and lead) were present at levels that exceeded the Commercial Use SCOs.

Deep Subsurface Soils

Fill (brick, concrete fragments, and wood fragments) was encountered as deep as 25 feet bgs [elevation -3.79 feet] in FW-SB-34 beneath the footprint of the holder and approximately 30 feet bgs [elevation -9.01 feet] in FW-MW-13 outside the footprint of the holder. Cross-section D-D’ shows the fill and the approximate depth of the former gasholder foundation. Soil borings FW-SB-33 and FW-SB-33A encountered refusal at 13 feet bgs [elevation 8.76 feet] and 20.3 feet bgs [elevation 0.74 feet], respectively. The refusal is likely attributable to materials used to fill the holder based upon the depth. Soil boring FW-SB-34 encountered refusal at 31 feet bgs [elevation -9.79 feet] which is assumed to be the bottom of the holder.

No visual evidence of tar-related impacts was observed at Parcel V or along the adjoining ROWs. Petroleum-like and naphthalene-like odors were observed from as shallow as 6 feet bgs [elevation 15.76 feet] at FW-SB-33 and as deep as 31 feet bgs [elevation -9.79 feet] at FW-SB-34 within the footprint of the holder. Petroleum odors were also encountered intermittently in FW-SB-43 between 16.3 feet and 45 feet bgs [elevation 4.59 to -23.79 feet].

The petroleum impacts are likely associated with use of the property as a truck facility subsequent to MGP operations. Fuel oil USTs and spills have been documented at the Parcel and are summarized in the regulatory review above in subsection 1.4.

BTEX ranged from not detected in multiple samples to 54.09 mg/kg in FW-MW-14 (10 to 15 feet). Total PAH concentrations ranged from 1.552 mg/kg in FW-MW-13 (25 to 25.6 feet) to 7.971 mg/kg at FW-SB-33A (17 to 20.3 feet) within the holder foundation. Individual concentrations of VOCs (BTEX, acetone, and 2-butanone) and metals (lead and zinc) exceeded Unrestricted Use SCOs. No detected compounds exceeded the Commercial Use SCOs (Table 12).

Five soil samples were collected beneath the observed impacts in four soil borings: FW-SB-43 and FW-MW-12 through FW-MW-14. The samples were collected between 35 and 50 feet bgs (Table 12 and Figure 3). All concentrations in the samples were below the Unrestricted Use SCOs. These samples bound the vertical extent of observed impacts at this Parcel.

Physical Impacts

There were no impacts more significant than slight petroleum and tar odors at Parcel V, both inside and outside of the holder. Since no sheen, blebs, coatings, or NAPL were observed at Parcel V, it is not a source area and does not appear to contribute to downgradient impacts. No Physical Impacts Summary Table is provided because Parcel V is generally lacking in MGP-impacts. Based on the lack of MGP-impacts, this parcel could be separated from the remaining Site area.

4.1.2.6 Parcel VI

Five soil borings (FW-SB-29 and FW-SB-35, FW-MW-10/Well, GC-MW31I, and FW-MW-11) were completed at Parcel VI to evaluate the extent of MGP impacts to the northwest of the former Fulton MGP Site (Figure 3). Two of the borings (FW-MW-10 Well and GC-MW31I) were completed as monitoring wells.

Shallow Subsurface Soil

Fill (metal, ash, brick, clinker, concrete, and glass fragments) were encountered in the top 5 feet. No visible or olfactory evidence of tar-related impacts was observed in the top 5 feet of soils at or adjacent to Parcel VI. Petroleum-like odors were encountered from 2.5 to 4.5 feet bgs at FW-SB-35 and petroleum-stained soils with petroleum-like odors were observed from 4 to 5 feet bgs [elevation 4.3 to 3.3 feet] in FW-SB-29.

BTEX compounds ranged from not detected in GC-MW31I (3.5 to 4 feet) and FW-SB-29 (4 to 5 feet) to 10.9 mg/kg in FW-MW-10 (0 to 1 foot). Total PAH concentrations ranged from not detected in FW-SB-29 (4 to 5 feet) to 173.47 mg/kg in FW-MW-10 (0 to 1 foot) (Table 12). Concentrations of ethylbenzene, xylene and acetone (VOCs), PAHs, 4,4-DDT, and arsenic, copper, lead, mercury, nickel and zinc were detected above the Unrestricted Use SCOs. Only some PAHs and arsenic were detected at concentrations above the Commercial

Use SCOs. FW-MW-10 is located within the footprint of a fuel oil spill, unrelated to the former MGP, described in the environmental record search information presented above in subsection 1.4.

Deep Subsurface Soils

Tar-like odors and tar-staining observed at 5 feet bgs in FW-SB-29 are the shallowest tar-related impacts at Parcel VI. Tar-coated soil was encountered from 6.5 feet bgs to 31 feet bgs [elevation 1.8 to -22.7 feet] at this location with a tar-saturated soil interval observed from 13.5 to 15 feet bgs [elevation -5.2 to -6.7 feet]. Tar coating to layers of tar saturation were observed at FW-SB-35 from 15 feet bgs to 31 feet bgs [elevation -6.67 to -22.67 feet]. Deeper, intermittent tar impacts ranging from tar saturation and lenses of tar to tar-coated soils and sheen were also encountered in FW-SB-35 from 46 feet bgs [elevation -37.67 feet] to its termination depth at 105 feet bgs [elevation -96.67 feet].

The heaviest tar impacts (inter-bedded lenses of tar saturation and tar saturated soils were encountered in boring FW-MW-10 between approximately 32.5 to 50 feet bgs [elevation -25.06 to -42.5 feet] (Cross-section B-B', Figure 11). Intervals of tar saturated soils and soils with inter-bedded lenses of tar saturation were also observed in FW-MW-11 and FW-SB-10 between 70 feet bgs and 98 feet bgs [elevation -61.67 feet to -90.56 feet]. The deepest tar impacts were observed in FW-MW-11 at 128.5 feet bgs [elevation -120.96 feet] (Figures 11 and 12).

Within intervals of observed tar-related impacts, BTEX was detected between 108.96 mg/kg in a sample collected from GCMW-31I (35.75 to 36 feet) to 2,817 mg/kg in a sample collected from FW-MW-10 (45 to 50 feet) (Tables 3 and 12). Total PAH concentrations ranged between 317.9 mg/kg in a sample collected from FW-SB35 (104 to 105 feet) to 41,390 mg/kg in a sample collected from FW-SB-29 boring at 14 to 15 feet (Tables 3 and 12). Concentrations of BTEX, SVOCs (PAHs and dibenzofuran), dieldrin (pesticide) and nickel were detected above the Unrestricted SCOs. The presence of dieldrin is related to land uses that post-date the operation of the MGP. Concentrations of individual BTEX and PAH compounds exceeded the Commercial Use SCOs (Tables 3 and 12).

Two soil samples were collected beneath the tar impacts in soil borings FW-MW-11 and FW-SB-29, within the Nevins Street ROW (Table 12 and Figure 3). Below the tar impacts, BTEX was detected at 0.00195 mg/kg and total PAH concentrations were detected at 0.095 mg/kg in a sample collected from boring FW-MW-11 (139 to 140 feet). The sample from boring FW-SB-29 was collected from 60 to 65 feet bgs. All compound concentrations were below the Unrestricted SCOs (Table 12). These data bound the vertical extent of impacts at Parcel VI.

Cyanide was not detected in any samples collected at the Parcel.

Physical Impacts

The table below presents a summary of physical impacts more significant than odor and staining at Parcel VI.

Boring ID	Depth Intervals (ft bgs)	Physical Impact Observations
FW-SB-29	6.5-10, 25-27.5 10-13.5, 15-17, 20-25, 27.5-31 13.5-15	Tar blebs and globs Tar coated Tar saturated
FW-SB-35	15.75-18.5, 25-30, 61-65.1, 68-69, 104.5-104.75 23-25, 53-55.5, 80-85 30-31*, 46.5-47, 58-60*, 70.5-73 31-31.5, 55.5-58, 73-75 90-93	Tar coated Tar coated with saturated lenses Tar saturated Tar sheen Tar blebs
FW-MW-10/ GCMW-31S	30-32.4, 46.8-48.3 32.4-33.5, 48.3-50*, 77-78.8 33.5-35, 50-55, 58.4-60, 75-77, 80-88*, 90-95 35-44.3, 95-98 65-70	Tar blebs Tar saturated Tar coated Tar coated with saturated lenses Tar sheen
FW-MW-11	6-6.9 23.4-30, 43.4-45, 48.5-55*, 56.6-57.7, 65-65.8, 85-87.4, 95-96.7, 122.5-125, 126.5-127.5 45-47.8, 60-65, 80-82.7, 107.5-108, 109-110, 112.5-115*, 117.5-120, 126.2-126.5, 127.5-128.5 47.8-48.5, 82.7-85 90-95 96.7-97.7, 100-107.5, 108-109, 110-112.5*	Petroleum saturated lenses Tar coated Tar sheen Tar saturated Tar blebs and coated lenses Tar blebs

* Depth interval includes lenses of NAPL observation.

The observations above demonstrate that subsurface impacts at Parcel VI are primarily tar related, and that past migration of tar within this parcel had a downward, not lateral, trend. The presence of saturated intervals suggests there may be some active NAPL mobility.

Gowanus Canal Adjacent to Parcel VI

Five sediment cores were collected in the Gowanus Canal adjacent to Parcel VI. The table below presents a summary of physical impacts more significant than odor and staining.

Boring ID (elevation - ft NAVD88)	Depth Interval (ft below mudline)	Physical Impact Observations (elevation of tar impacts - ft NAVD88)
ERT 2-1	7-8.5	Petroleum sheen
ERT 2-2	0-7.5	Petroleum sheen
ERT 2-3	0-11.5	None observed
GC-SED-04 (-5.23)	0-2, 11-11.3 11.3-20	Petroleum sheen Tar coated (-16.53)
GC-SED-05 (-5.23)	13.5-14.5 15-20	Tar coated (-18.73) Tar coated

The shallowest impacts are petroleum-related. Coal tar impacts are apparent in deeper locations.

The closest landside boring to GC-SED-05 is FW-MW-10, where tar blebs were present at 1.09 feet NAVD88. This is much higher than GC-SED-04 (-16.53) and GC-SED-05 (-18.73).

4.1.2.7 Parcel VII

Four soil borings (FW-SB-51/FW-MW-23D2, FW-MW-23D1, FW-MW-23I, and FW-MW-23S) were installed to evaluate MGP-related impacts to the northwest of the Fulton former MGP Site and the north of Parcel VI (Figure 3). Each boring was completed as a monitoring well.

Three borings were completed within the Nevins and Butler Street ROWs. GC-MW-33S/I was installed within the Nevins Street ROW. FW-SB-42 and FW-MW-20 were installed within the Butler Street ROW.

Shallow Subsurface Soils

The property was paved with concrete and asphalt. Fill (bricks, ash, wood particles, clinker, glass, paper) was encountered in each boring. Petroleum-like odors were observed between 2.7 and 5.0 feet bgs at the location of FW-SB-51. No tar-related impacts (visual or odor) were observed in shallow subsurface soils on Parcel VII or in the adjacent ROWs. No soil samples for laboratory analyses were collected in the top 5 feet.

Deep Subsurface Soils

On Parcel VII, fill consisting of sand with silt and gravel and containing paper, glass, brick, and ash was observed as deep as 8 feet bgs at FW-SB-51. Fill was observed deeper along Nevins Street (15.5 feet bgs at GCMW-33) and along Butler Street (20 feet bgs at FW-SB-42). Petroleum-like odors were observed in the fill at FW-SB-51 to a depth of 8.1 feet bgs. Petroleum-like odors were also observed in soils at GCMW-33I between 24.5 feet and 29 feet bgs [elevation -17.19 feet to -21.69 feet].

The only tar-related impacts observed on or adjacent to Parcel VII were tar-like odors and sheen in an isolated interval from 63.2 feet bgs to 66.8 feet bgs at FW-SB-51. No other visual or olfactory observations of environmental impacts were observed.

Two soil samples were collected in the fill: FW-MW-23S (5 to 6 feet) and GCMW-33 5 to 10 feet). BTEX concentrations ranged from 0.0012 mg/kg in FW-MW-23S to 0.00503 mg/kg in GCMW-33I. Total PAH concentrations were 0.026 mg/kg to12.58 mg/kg in GC-MW33 and FW-MW-23S, respectively. Acetone (VOC), Indeno[1,2,3-cd]pyrene (a PAH), and metals (arsenic, copper, lead, and mercury) were detected at concentrations that exceeded the Unrestricted Use SCOs. Only arsenic was present at 41.7 mg/kg, which is above the Commercial Use SCO of 16 mg/kg (Table 12).

A sample collected from 20 to 25 feet had a BTEX concentration of 5.827 mg/kg and a total PAH concentration of 2.386 mg/kg. Concentrations of benzene and ethylbenzene were present at concentrations that exceeded the Unrestricted Use SCOs. All concentrations were below the Commercial Use SCOs.

BTEX concentrations in the tar-odor and sheen interval (64 to 66 feet bgs) at FW-SB-51 were 39.39 mg/kg and the total PAH concentration was 987 mg/kg. Ethylbenzene and total xylenes (VOCs), total PAHs, and nickel were detected at concentrations above the established Unrestricted SCOs. Concentrations of individual PAH compounds were present above the Commercial Use SCOs (Table 12).

Three soil samples were collected beneath the impacted zone in soil borings FW-MW-23D1(primary sample and blind duplicate collected between 112-113 feet bgs) and FW-MW-23D2/FW-SB-51 (sample collected between 147-149 feet bgs). Two samples were also collected between 55 - 60 and 75 - 79 feet bgs in FW-SB-42 beneath the sidewalk of the Butler Street ROW.

In soil samples collected above and below the tar-impacted interval, BTEX and PAHs compounds were either not detected or present at concentrations below the Unrestricted Use SCOs (Table 12). Only one detection of nickel ([49.6 mg/kg] in FW-SB-42 75 to 79 feet) was present at a concentration above the Unrestricted SCO. All concentrations were at levels below the Commercial SCOs. These data bound the vertical extent of MGP-related environmental impacts at Parcel VII. Cyanide was not detected in any samples collected at the parcel.

Gowanus Canal Adjacent to Parcel VII

Ten sediment cores were collected in the Gowanus Canal adjacent to Parcel VII. The table below presents a summary of physical impacts more significant than odor and staining.

Boring ID (elevation - ft NAVD88)	Depth Interval (ft below mudline)	Physical Impact Observations (elevation of tar impacts - ft NAVD88)
ERT 1-1	0-7	None observed
ERT 1-2	0-3	Petroleum sheen
ERT 1-3	0-13	None observed
GC-SD107	0-10	None observed
GC-SED-01 (-3.8)	1-2.5 17.2-20	Petroleum sheen Tar coated (-21.0)
GC-SED-02 (-3.07)	1-2 17.1-18.1	Petroleum sheen Tar sheen (-20.17)
GC-SED-03B	0-9.3	Sheen
GC-SD124 (-9.6)	2-4	Tar saturated (-11.6)
GC-SD125 (-1.9)	12-13.6	Tar saturated (-13.9)
GC-SD126	0-6.5	None observed

4.1.2.8 Parcel VIII (West of Gowanus Canal)

One soil boring (FW-SB-45) was drilled at Parcel VIII in the bituminous paved parking area adjacent to the Gowanus Canal bulkhead (Figure 3). Parcel VIII was not part of the operating footprint of the former MGP and is included in this report because access was negotiated with the property owner for installation of the soil boring.

Shallow Subsurface Soils

Fill (wood, slag, and cobblestones) were encountered in the top 5 feet of FW-SB-45. No visual or olfactory evidence of environmental impacts were observed in the top 5 feet of soil at this location. No soil samples for laboratory analyses were collected in the top 5 feet.

Deep Subsurface Soils

Fill (wood, slag, and cobblestones) were encountered to a depth of 30 feet bgs [elevation -25.32 feet] (Cross-section C-C', Figure 11).

The shallowest tar-related impacts (tar coated, staining, and sheens) were observed at 25 feet [elevation -20.32 feet] and as deep as approximately 107 feet bgs [elevation -102.62 feet] (Cross-section C-C', Figure 11). Within this zone, intervals with varying degrees of tar coating, staining, and sheens were encountered. An interval of tar-saturated soil was encountered from approximately 39 to 42 feet bgs [elevation -34.32 to -37.32 feet]. A sample collected from tar-saturated soils at 40 to 41 feet bgs had a BTEX concentration of 3,290 mg/kg and total PAH concentration of 26,050 mg/kg. Concentrations of individual BTEX compounds and SVOCs (PAHs and dibenzofuran) exceeded the Unrestricted Use SCOs. Individual BTEX and PAH concentrations also exceeded the Commercial Use SCOs (Tables 3 and 12).

One sample [FW-SB-45 (119 to 120 feet)] was collected beneath the tar-related impacts. BTEX was not detected and total PAHs were detected as 1.96 mg/kg. All concentrations were below the Unrestricted SCOs (Table 12). These data bound the vertical extent of tar-related impacts at this location.

Cyanide was not detected in either of the samples collected at the parcel.

Physical Impacts

The table below presents a summary of physical impacts more significant than odor and staining at Parcel VIII.

Boring ID	Depth Intervals (ft bgs)	Physical Impact Observations
FW-SB-45	25-30, 32-33, 35-38.7, 45-45.7, 60-62.6*, 86.1-86.6 30-32, 33-35, 50-54, 62.6-65, 66.3-73.5, 75-80, 85-86.1, 86.6-89.5, 90-94.3, 100-105.8 38.7-41.6 41.6-45, 80-85	Tar coated Tar coated Tar sheen Tar sheen Tar saturated Tar saturated Tar blebs
GC-GP-05/ FW-SB-46[+]	27-27.2, 32-38 27.2-32, 40-40.8, 45.8-46.3*, 57.1-57.9 70-70.6	Tar saturated Tar coated Tar blebs
FW-MW-22I[+]	29.5-30	Tar coated

* Depth interval includes lenses of NAPL observation.
[+] Borings are near Parcel VIII but not within the parcel boundary.

While there may be more than one source for the impacts summarized above, it is likely that at least some of the impacts are related to the Fulton site.

Gowanus Canal Adjacent to Parcel VIII

Three sediment cores were collected in the Gowanus Canal adjacent to Parcel VIII. The table below presents a summary of physical impacts more significant than odor and staining.

Boring ID (elevation - ft NAVD88)	Depth Interval (ft below mudline)	Physical Impact Observations (elevation of tar impacts - ft NAVD88)
ERT 2-1	7-8.5	Petroleum sheen
ERT 2-2	0-7.5	Petroleum sheen
ERT 2-3	0-11.5	None observed

While the core depths are limited, the sole observations of petroleum-related impacts are significant. There were no shallow petroleum-related impacts in the nearest landside borings on either side of the canal (FW-SB-45 or FW-MW-10). This is additional evidence that subsurface migration from the Site and into the sediments is not necessarily the primary mechanism of tar emplacement.

At FW-SB-45 (Parcel VIII), located across the canal from Parcel VI, tar coatings were present at elevation -20.32 feet, deeper than those in the canal.

4.1.3 Lateral Extent Delineation

4.1.3.1 Northern Extent

The lateral extent of tar-related impacts was bounded to the north by the following borings, where no evidence of tar-related impacts was observed (visual, olfactory):

- SB01S/I (MW01S/I) – total depth 40 feet bgs
- FW-SB-52 – total depth 85 feet bgs
- FW-SB-40 – total depth 60 feet bgs
- FW-SB-39 – total depth 55 feet bgs

The boring locations are shown in Figure 3.

The only visible evidence of tar-related impacts was an isolated lens of sheen and tar stained and coated grains at 34.8 to 37 feet bgs in FW-SB-41.

Two soil samples were collected from each of borings FW-SB-39, FW-SB-40, FW-SB-52 at depths corresponding to impacted zones located to the south and at the termination depth of each soil boring. Each sample was non-detect for total BTEX, total PAHs, and cyanide confirming that the northern extent of tar-related impacts has been bounded.

Physical impacts were also not observed in SB01I/GCMW-01I to a depth of 40 feet bgs. In a sample collected from 35 to 40 feet at the completion of SB01I/GCMW-01I, all detected compounds with the exception of acetone, were below the Unrestricted Use SCOs. Acetone is a common laboratory solvent.

4.1.3.2 Southern Extent

The lateral extent of tar-related impacts was bounded to the south by the following borings, where, with one exception, no evidence of tar-related impacts was observed (visual, olfactory):

- FW-MW-04 – total depth 50 feet bgs
- FW-MW-4R – total depth 16 feet bgs
- FW-SB-37 – total depth 80 feet bgs
- FW-SB-38 – total depth 68 feet bgs

The boring locations are shown in Figure 3.

The only visible evidence of tar-related impacts was an isolated lens of tar at 53 to 53.5 feet bgs in FW-SB-37. Petroleum odor and staining was also observed in FW-SB-37 from 10 feet to 30 feet (Cross-section B-B', Figure 11). This boring is located downgradient of the Verizon property which is currently being remediated for petroleum releases as part of NYSDEC Spill# 92-07367, as discussed in subsection 1.4 (Figure 3). The petroleum impacts observed at FW-SB-37 are attributed to the Verizon spill.

Soil samples from FW-SB-37 (50 to 55 and 75 to 80 feet bgs) and FW-SB-38 (50 to 55 and 65 to 68 feet bgs) confirm that with the exception of the 65 to 68 foot interval in FW-SB-38, total BTEX, total PAHs, and total cyanide were either non-detect or below the Unrestricted SCOs. Analytical results for the sample from the 65 to 68 foot interval of FW-SB-38 were below the Unrestricted Use SCOs for BTEX and were non-detect for cyanide, but a few individual PAHs exceeded the Unrestricted Use and Commercial Use SCOs. These analytical results confirm that the lateral extent of tar-related impacts has been bounded on the south of the RI study area.

4.1.3.3 Eastern Extent

The following borings completed on Parcel II and the adjoining Douglass Street document that the eastern extent of tar-related impacts has been bounded at the Site:

- FW-SB-39 – total depth 55 feet bgs
- FW-MW-07 – total depth 55 feet bgs
- FW-MW-06 – total depth 60 feet bgs

The boring locations are shown in Figure 3.

No visual or olfactory observations of tar-related impacts were observed in any of these borings. Analytical results indicate that BTEX, PAHs, and cyanide concentrations for samples were either non-detect or below the Commercial SCOs. MGP-related impacts were not observed on Parcel V either, located further to the east. The findings from Parcel V are discussed further in subsection 4.1.2.5.

4.1.3.4 Western Extent (West Side of Gowanus Canal)

In addition to FW-SB-45 installed on Parcel VIII (discussed above), the following soil borings were completed to the west of the Gowanus Canal.

- FW-SB-44, and FW-SB-46, FW-SB-47, FW-SB-48, FW-SB-49, FW-SB-50, FW-MW-21S/I, and FW-MW-22S/I
- GC-GP-05 and GC-GP-07
- SB02S/I(MW02S/I), GCMW-03, GCMW-04 and GCMW-34

The former Fulton RI soil borings were completed to define the impacts to the west/ northwest of the former Fulton MGP and to bound impacts encountered in GC-GP-05 and GC-GP-07.

The only environmental impacts observed (visual and olfactory) on the west side of the Gowanus Canal were in borings completed nearest the Canal (FW-SB-45 [Parcel VII], FW-SB-46, FW-SB-49, GCMW-03, GCMW-34). The findings for FW-SB-45 [Parcel VIII] are discussed above in subsection 4.1.2.8. The findings forFW-SB-46, FW-SB-49, GCMW-03, and GCMW-34 are discussed below.

The lateral extent of tar-related impacts was bounded on the west side of the Gowanus Canal by the following borings, where no evidence of tar-related impacts was observed (visual, olfactory):

- FW-SB-44 – total depth 125 feet bgs
- FW-SB-47 – total depth 120 feet bgs
- FW-SB-48 – total depth 110 feet bgs
- FW-SB-50 – total depth 125 feet bgs
- SB-02S/I (GCMW-02S/I) – total depth 36 feet bgs
- GCMW-04 – total depth 37 feet bgs

The boring locations are shown in Figure 3.
Physical impacts were not observed in borings installed between 110 and 125 feet bgs [elevation -101.39 feet to -119.61 feet].

Analytical samples were collected from borings FW-SB-44, FW-SB-47, FW-SB-48, and FW-SB-50 at elevations corresponding to tar-impacted zones at borings closer to the Canal. All detected compounds were at concentrations below the Unrestricted Use SCOs, thereby, confirming that the lateral extent of impacts has been defined.

Physical impacts also were not observed in GCMW-02I to a depth of 36 feet bgs. In a sample collected from 35 to 36 feet) at the completion of GC-MW02I, all detected compounds with the exception of acetone, were below the Unrestricted Use SCOs. Acetone is a common laboratory solvent.

These borings and wells define the clean boundary on the western side of the Gowanus Canal.

Impacts Near Canal - Shallow Subsurface Soils

Fill (concrete and sand fill) were observed in shallow subsurface soils. Petroleum saturated soils were observed in the top five feet during the utility clearance for the borehole. An analytical sample was collected from GC-GP-07 (2 to 3 feet) within the fill. The boring was completed on and immediately adjacent to the Former Bayside Fuel Depot property, which is a former major fuel oil storage facility. The property is being investigated and remediated under NYSDEC spill no. 0902825, and the petroleum impacts observed are likely related to the Bayside Fuel Depot.

BTEX was detected at 0.0135 mg/kg at concentration below the Unrestricted Use SCOs. Total PAHs were detected at 94.47 mg/kg. Concentrations of individual PAH compounds and metal compounds (lead and mercury) were present at levels above the Unrestricted SCOs. Concentrations of BAP (a PAH), (arsenic, barium, lead, mercury and zinc) was present above the Commercial Use SCO.

Impacts Near Canal - Deep Subsurface Soils

Fill (concrete, ash, tile fragments, and wood particles) was observed to a depth of 22.5 feet bgs [elevation -17.5 feet]. An analytical sample collected from FW-SB-44 (8 feet to 10 feet) within the fill exhibited a petroleum-like odor and grey staining. BTEX was not detected and total PAHs were detected at 15.26 mg/kg. BTEX and PAH compounds were present at levels below the Unrestricted SCOs. Concentrations of metals (arsenic, barium, lead, mercury, and zinc) were detected above the Unrestricted Use SCOs. Arsenic was detected at a concentration that exceeded the Commercial Use SCO. Given the lack of organic compounds, the metals and arsenic are not likely MGP-related.

Oil-saturated soils with strong petroleum-like odors were observed from 5 to 5.75 feet bgs [elevation -1.29 feet to -2.04 feet] and black staining and soils exhibiting sheens were observed between 8.5 feet and 13 feet bgs [elevation -4.79 feet to -9.29 feet] in GC-GP-07 within the Sackett Street ROW. Spotty petroleum hydrocarbon sheens were also observed in GC-MW-03 from 5 to 8 feet bgs [elevation 1.62 feet to -1.38 feet] [Cross-Section C-C', Figure 11). The boring was completed on and immediately adjacent to the Former Bayside Fuel Depot property, which is a former major fuel oil storage facility. These impacts do not appear to be MGP-related and the property is being investigated and remediated under NYSDEC spill no. 0902825.

The shallowest tar impacts were encountered in FW-SB-49 at 18 to 22 feet bgs where tar-coated soil to tar-saturated soil was observed. As shown on cross-section C-C’, Figure 11, a zone of heavily-coated to tar-saturated soils was observed in borings GC-GP-05 and GC-GP-07 between 18 and 40 feet bgs [elevation -14.29 feet and -36.29 feet]. Soils saturated with low to medium viscosity petroleum hydrocarbon materials (HDR, et al, 2010) were also observed in USEPA borings GC-MW34 between 18 to 33 feet bgs [elevation -13 and -28 feet] and in GC-MW-03 between 18 and 20 feet bgs [elevation -11.38 and -13.38 feet] and 29 to 38 feet bgs [elevation -22.38 and -31.38 feet].

Intermittent layers of tar-saturated soils were observed in FW-SB-49 from 63.2 to 70 feet bgs [elevation -57.87 to -64.67 feet] and 80 to 81.3 feet bgs [elevation -74.67 to -75.97 feet]. The deepest interval of tar-impacted soils within the street ROWs was to the west of the Canal at a depth of 100 feet bgs [elevation -94.67 feet] in FW-SB-49 (Cross-section C-C', Figure 11).

Within the impacted soils, BTEX concentrations ranged from 0.0034 mg/kg in FW-SB-49 (67 to 69 feet) to 2,188 mg/kg in FW-SB-46 (40 to 41 feet). Total PAHs concentrations ranged from 1.169 mg/kg in FW-SB-49 (67 to 69 feet) to 24,710 mg/kg in GC-GP-05 (33 to 35 feet). Cyanide was not detected in any of the samples collected in the borings to the west of the Gowanus Canal (Tables 2, 3 and 12).

VOCs (BTEX, methylene chloride, 1,2-Dichlorobenzene, 1,3-Dichlorobenzene, 1,4-Dichlorobenzene), SVOCs (PAHs and dibenzofuran), pesticides and nickel were present at concentrations that exceeded the Unrestricted Use SCOs. The presence of chlorinated VOCs (methylene chloride, 1,2-Dichlorobenzene, 1,3-Dichlorobenzene, 1,4-Dichlorobenzene) and pesticides is related to land uses that post-date the operation of the MGP. Individual BTEX and PAH compounds exceeded the Commercial Use SCOs (Tables 2, 3 and 12).

Physical Impacts

The table below presents a summary of physical impacts more significant than odor and staining west of the Gowanus Canal.

Boring ID	Depth Intervals (ft bgs)	Physical Impact Observations
FW-SB-45	25-30, 32-33, 35-38.7, 45-45.7, 60-62.6*, 86.1-86.6 30-32, 33-35, 50-54, 62.6-65, 66.3-73.5, 75-80, 85-86.1, 86.6-89.5, 90-94.3, 100-105.8 38.7-41.6 41.6-45, 80-85	Tar coated Tar coated Tar sheen Tar sheen Tar sheen Tar saturated/Tar blebs
GC-GP-05/ FW-SB-46	27-27.2, 32-38 27.2-32, 40-40.8, 45.8-46.3*, 57.1-57.9 70-70.6	Tar saturated Tar coated Tar blebs
FW-SB-49	18.1-20, 78.8-79.5, 93.6-95*, 98.3-100 20-21.4, 63.2-70, 80-81.3 60-63.2, 77.5-78.8, 79.5-80 81.3-81.9, 95-98.3	Tar coated Tar saturated Tar blebs Tar sheen
FW-MW-22I	29.5-30	Tar coated
GCMW-03S,I	17-18, 25-26 18-20, 22-22.3, 29-34, 34-37*, 37-38	Petroleum hydrocarbon sheen Petroleum hydrocarbon saturated
GCMW-34S,I	18-23, 23.75-24.75, 29.9-30.5, 32.5-33 24.75-25.25 27-28, 30.5-32.5*	Petroleum hydrocarbon saturated Petroleum hydrocarbon sheen Petroleum hydrocarbon coated
GC-GP-07	5-5.75 11.25-13 19-20, 25-30, 39-40 20-25 30-35	Petroleum saturated Petroleum sheen Tar saturated Tar stained with saturated lenses Tar blebs

* Depth interval includes lenses of NAPL observation.

These observations assist in illustrating how some tar has migrated from the Site and beneath the canal, to depths of up to 95 feet bgs. They also highlight the widespread presence of petroleum impacts. The potential sources of petroleum impacts are many, as described in subsection 1.2.1.3.

4.2 Groundwater Analytical Results

Discussion of the groundwater analytical data is divided into four intervals by aquifer and depth:

- Upper Glacial Aquifer
  - Shallow groundwater zone (groundwater table)
  - Intermediate groundwater zone
  - Deep groundwater zone
- Jameco Aquifer

A summary of detected analytes in groundwater is provided in Table 13. A summary of detected groundwater analytical data from the USEPA's Gowanus Canal RI is included in Table 4. A summary of total BTEX, total PAHs, and cyanide is presented in Figures 14 and 15, with shading to identify exceedances of the NYSAWQSs. Groundwater elevations, monitoring well construction details, and groundwater zones are provided in Tables 7 and 8.

Analysis of dissolved phase groundwater samples collected as part of the RI identified concentrations of compounds that were above NYSAWQSs that are likely related to MGP impacts and post-MGP petroleum storage, spills and solvent use. Groundwater in the RI study area contained elevated concentrations naturally occurring metals (iron, magnesium, manganese, and/or sodium) indicative of the natural groundwater conditions in the area. The analytical results of iron, magnesium, manganese, and sodium are not discussed in this section because they are considered naturally occurring.

Drinking water is supplied to the Fulton MGP Site and surrounding area by the City of New York municipal water system.

4.2.1 Shallow Groundwater Zone

The following section summarizes the findings from the shallow groundwater (water table) zone of the Upper Glacial Aquifer. The RI study area findings are separated into the areas to the east and to the west of the Gowanus Canal.

East of the Gowanus Canal

Thirty-one monitoring wells and six temporary groundwater points are located in the shallow zone of the Upper Glacial Aquifer to the east of the Gowanus Canal. NAPL blebs and petroleum odors were observed in two monitoring wells FW-MW-1R and FW-MW-03 and samples from the wells were not submitted for laboratory analysis as discussed in subsection 2.6.1.

As discussed in subsection 3.2.1, groundwater in the water table aquifer generally flows from FW-MW-19 and FW-MW-14 westerly and southwesterly toward and discharging to the Gowanus Canal.

Concentrations of BTEX in shallow groundwater ranged from not detected in nine monitoring wells to a maximum of 8,770 µg/L in FW-MW-14 upgradient of the Fulton Former MGP Site (Figure 14 and Tables 4 and 13). FW-MW-14 was screened in soils where staining and petroleum odors were noted. Odors were also observed during the gauging event conducted on May 19, 2011. As discussed in subsection 1.4, a number of fuel oil USTs and spills of fuel oil post-dating and unrelated to the former MGP operation have been documented in the area. The elevated BTEX and observed petroleum odors in groundwater samples are attributed to these more recent petroleum releases. The highest BTEX concentration associated with the former MGP operations was in a groundwater sample collected from well FW-GW-11 (Parcel III), immediately adjacent to the former gas holder foundation in tar-impacted soils. In general, BTEX compounds exceeded the NYSAWQSs when they were detected.

MTBE was detected at concentrations that exceeded the NYSAWQS of 10 µg/L in six monitoring wells (FW-MW-01 and FW-MW-02 [Parcel I], FW-MW-03 [Nevins Street ROW], FW-MW-17 [Degraw Street ROW], FW-MW-05 [Parcel IV], and FW-MW-18 [Union Street ROW]). MTBE is an additive used in gasoline and is not MGP-related.

Chlorinated VOCs, including TCE, PCE, cis-1,2-dichloroethene, and/ or PVC, were detected at concentrations above the NYSAWQSs at three locations (FW-GW-16 [Parcel III], FW-MW-04 [Parcel III] and FW-MW-4R downgradient of Parcel III]). As discussed in subsection 1.2.1, the Majestic Metal Spinning & Stamping Company, Inc. previously operated on Parcel III from 1950 until circa 1982. According to Sanborn maps, plating and spraying operations were previously included on the eastern side of the warehouse building. Chlorinated compounds were commonly used as degreasing agents at metal works, and are unrelated to the former MGP operations.

Concentrations of total PAHs ranged from not detected in six monitoring wells to maximum of 11,087 µg/L in KSF-MW-6 within the Degraw Street ROW adjacent the former hydrogen tank (gas holder foundation) and downgradient from former gas oil/ oil tanks. The highest concentrations of PAHs were detected within or adjacent to the gas production area (Parcel I), former MGP gas holder at Parcel III, and the gas holder and petroleum tanks (Parcels II, III, and IV). Concentrations of individual PAHs were present at levels above the NYSAWQSs.

Other SVOCs (1,1 biphenyl, phenol, 2-methylphenol, and 4-methylphenol) were also detected in GC-MW30S/FW-MW-01, FW-GW-11, KSF MW-07, FW-MW-14, and FW-MW-18 at concentrations that exceeded the NYSAWQSs.

Total cyanide was not detected in multiple samples. The highest total cyanide concentration was 495 μg/L in FW-GW-11 collected adjacent to the former gas purifying houses at Parcel III. Only one other sample (FW-MW-05) contained concentrations above the NYSAWQS of 200 μg/L.

Concentrations of metals (arsenic, barium lead, mercury, nickel, copper and/or thallium) were detected in five temporary monitoring wells (FW-GW-20, FW-GW-16, FW-GW-15, FW-GW-34, and FW-GW-43) and four monitoring wells (FW-MW-06, FW-MW-08, FW-MW05R, and FW-MW-14). All the wells were screened within fill. The highest frequency of exceedances was in groundwater samples collected from the temporary groundwater well. It is likely that the elevated metals concentrations are attributable to suspended solids that were entrained in the groundwater sample during sampling.

Pesticides (BHC compounds, dieldrin, and heptachlor compounds) were detected in FW-MW-02 [Parcel I], FW-GW-20 and FW-MW-16 [Parcel II], FW-MW-10 [Parcel VI], and wells within street ROWs (FW-MW-03, KSF-MW-2, FW-MW-09, KSF-MW-07, FW-MW-09, and FW-MW-14). These compounds are not MGP-related.

West of the Gowanus Canal

Six monitoring wells were installed in the shallow zone of the Upper Glacial Aquifer to the west of the Gowanus Canal. FW-MW-21S and FW-MW-22S, GCMW-02S, GCMW-03S, GCMW-04S and GCMW-34S are located in the shallow zone of the Upper Glacial Aquifer within the Fulton RI study area to the west of the Gowanus Canal.

The shallow groundwater to the west of the Gowanus Canal flows generally easterly, ultimately discharging to the Canal. There were no MGP-related structures on the western side of the Gowanus Canal. As such, shallow groundwater impacts are likely associated with the other previous or current activities.

BTEX was only detected in two monitoring wells: GCMW-34S at 3.72 μg/L and GCMW-03S at 8.48 μg/L with individual BTEX concentrations below the NYSAWQSs. MTBE was detected in GC-MW04S and chlorinated VOCs (TCE and PCE) were detected in FW-MW-21S at levels above the NYSAWQSs (Figure 14 Tables 4 and 13). MTBE and chlorinated VOCs are not MGP-related.

PAHs were not detected in wells GC-MW02S, FW-MW-21, and FW-MW-22. The highest concentration of total PAHs (225.3 µg/L) was in the sample collected from well GCMW-34S. The highest concentrations of individual PAHs were detected in GCMW-03S and GCMW34S. GCMW-03S is located on the former Bayside Fuel Oil property, a state-listed spill and a former MOSF. GCMW-34S is located on a property which is currently used for fuel oil delivery truck parking. The PAHs detected in these samples are likely associated with the former Bayside Fuel Oil facility.

Total cyanide was not detected in any of the wells to the west of the Gowanus Canal.

4.2.2 Intermediate Groundwater

East of the Gowanus Canal

Five wells were installed to evaluate the groundwater conditions on the eastern side of the Gowanus Canal at intermediate depths: GC-MW30I [Parcel I], GC-MW31I [Parcel IV], GC-MW32I [Parcel II], FW-MW23I [Parcel VII], and GC-MW33I [Nevins Street ROW] (Figures 3, 15, and 16). A sixth well, GC-MW-01I located at the head of the Gowanus Canal, is included in the discussion because of its proximity to the eastern side of the Gowanus Canal.

Intermediate depth groundwater on the eastern side of the Gowanus Canal flows westerly to southwesterly (Figures 15 and 16).

BTEX concentrations ranged from not detected in FW- MW-23I [Parcel VII] to 12,690 µg/L in GCMW-02I [Parcel II]. Concentrations of individual BTEX compounds, MTBE and isopropyl benzene in GC-MW30I to GC-MW33I exceeded the NYSAWQSs. MTBE is not MGP-related and detection of MTBE indicates an upgradient fuel release is impacting the groundwater beneath the Site (Figure 15 and Tables 4 and 13).

Chlorinated VOCs (chloroform, TCE, PVC, 1,1-Dichloroethane, cis 1,2-dichloroethane, and/or trichlorofluoromethane) and acetone were also detected above NYSAWQs in FW-MW-23I, GCMW-33I, and GCMW-01I near the head of the Gowanus Canal. The chlorinated compounds are unrelated to the former MGP operations and represent releases that post-date the MGP.

Total PAH concentrations ranged from 10.92 µg/L in GCMW-01I [top of Canal] to 15,893 µg/L in GCMW32I [Parcel II]. Concentrations of individual PAHs and 1,1 biphenyl exceeded the NYSAWQSs in GC-MW-30I through GCMW-33I. Only acenaphthene (PAH) exceeded the NYSAWQSs in FW-MW-23.

Total cyanide was detected in two monitoring wells (FW-MW23I and GCMW-31I) at 11.3 μg/L and 22.4 μg/L, respectively, well below the NYSAWQS. Free cyanide was not detected in FW-MW31I.

Beta-BHC (a pesticide) was detected in GCMW-31I above the NYSAWQS. Pesticides in groundwater are unrelated to the former MGP operations.

West of the Gowanus Canal

Six monitoring wells were installed to evaluate the intermediate groundwater conditions on the western side of the Gowanus Canal: GCMW-02I (Gowanus Pump Station), FW-MW-21I and FW-MW-22I (Degraw Street ROW), GC-MW04I (Sackett Street), and GCMW-34I and GCMW-03I on private properties adjacent to the Gowanus Canal (Figures 3 and 15). As discussed above, FW-MW-22I was not submitted for laboratory analysis because tar was observed in groundwater sampling tubing during the sample collection.

On the western side of the Gowanus Canal, intermediate depth groundwater flows east to the southeast beneath the Gowanus Canal.

BTEX concentrations ranged from not detected in four monitoring wells (FW-MW-21I and GC-MW02I through GCMW-04I) to 1.57 μg/L in GCMW-34I.

Chlorinated VOCs, (TCE, cis-1,2-Dichloroethene, chloroform, PCE, and PVC), unrelated to the former MGP operations were detected in each of the intermediate monitoring wells at levels above the NYSAWQSs.

Total PAH concentrations ranged from an estimated concentration of 0.55 μg/L at FW-MW-21I to 861.1 μg/L in GC-MW-34 next to the Gowanus Canal bulkhead. GCMW-34 is screened within a coarse soil that was saturated with low viscosity petroleum hydrocarbon NAPL and faint to moderate petroleum hydrocarbon odors. Individual PAH compounds were present at levels that exceeded the NYSAWQSs in GCMW-01I through GCMW-04I and GCMW-34I. Bis(2-ethylhexyl)phthalate, a plasticizer-related compound, was detected in GCMW-04I at a level that exceeded NYSAWQS.

Cyanide was not detected in groundwater within the intermediate zone to the west of the Gowanus Canal.

4.2.3 Deep Groundwater Zone

Groundwater conditions in the deep zone of the Upper Glacier Aquifer were evaluated through the collection of groundwater samples from two monitoring wells, FW-MW-23D1 and GCMW-30D1 (Figure 3). The wells were installed adjacent to the eastern bulkhead of the Gowanus Canal. GCMW-30D1 was installed on Parcel I adjacent to the MGP gas production area and FW-MW-23D1 was installed on Parcel VII to the northwest of the former Fulton MGP Site. The monitoring wells were screened between 112 and 117 feet bgs [elevation -102.8 to -110.16 feet].

BTEX concentrations ranged from not detected in FW-MW-23D1 to 151.3 µg/L in GC-MW30D1. Total PAH concentration ranged from not detected in FW-MW23D1 to 275.62 µg/L (Table 4 and 13). Concentrations of individual BTEX compounds (benzene, ethyl benzene, and xylene) and PAHs (acenaphthene and naphthalene) were detected above NYSAWQSs in GCMW-30D1
MTBE and isopropyl benzene were detected in GC-MW30D1 and MTBE and chloroform (chlorinated VOC) were detected in FW-MW-23D1 at concentrations above the NYSAWQSs. Isopropyl benzene, like MTBE, is a common gasoline-related compound. The presence of these two compounds at depth suggests an upgradient release.

Total cyanide was not detected in FW-MW-23D1 and GCMW-30D1.

4.2.4 Jameco Aquifer

Two monitoring wells (FW-MW-23D2 and GCMW-30D2) were screened within the Jameco Aquifer.

As discussed above in subsection 3.2, the Jameco Aquifer was screened between 142 feet and 151.1 feet [elevation 133.3 to -144.62 feet].

BTEX, total PAHs, and cyanide were not detected in FW-MW-23D2; however, concentrations of chloroform (a chlorinated VOC) and MTBE were detected above NYSAWQS level. These compounds are not associated with MGP operations and are associated with chlorinated solvents and gasoline.

BTEX, cyanide, PCBs, pesticides, and herbicides were not detected in GCMW-30D2. Total PAHs were detected at a concentration of 1.8433 µg/L. Individual concentrations of PAHs were present above the NYSAWQSs (Tables 4 and 13). A number of PAHs detected were heavy molecular weight PAHs [e.g. BAP] that are not readily soluble. GCMW-30D2 was screened approximately 25 feet below the last observed impacts at 105.5 feet bgs (Cross-section B-B', Figure 11). The PAH concentrations are likely associated with sediments within cloudy water observed during the collection of the groundwater sample.

4.3 Soil Vapor, Indoor Air, and Ambient Air (Outdoor) Analytical Results

Soil vapor was sampled at Parcels I through Parcel V. SVI investigations, including the collection of soil vapor, indoor air, and ambient (outdoor air) samples, were completed within occupied buildings at Parcels I, III and Parcel V. Soil vapor, indoor and outdoor (ambient air) air analytical data is provided in Table 14.

4.3.1 Parcel I

Sub-slab Soil Vapor

Soil vapor samples were collected from four sub-slab soil vapor points (FW-SV-01 through FW-SV-04). The samples were collected on July 31, 2008, outside the winter heating season and on March 16, 2009 during the winter heating season.
Helium gas was present above the NYSDOH recommended value of 10% in two soil vapor samples (FW-SV-01 and FW-SV-03) during the July 2008 sampling event. Ambient air leakage occurred around the points so the soil vapor data for the 2008 event are not representative of soil vapor conditions. The remaining sample data had minimal air leakage and the results are representative subsurface conditions.

Compounds that are common to MGP operations and petroleum products (including BTEX compounds and naphthalene) were detected in sub-slab soil vapor samples. Concentrations of compounds common to gasoline (n-octane, n-hexane and n-heptane) were also detected in each soil vapor sample (Table 14).

Concentrations of chlorinated solvents, TCE, and PCE were detected in each soil vapor sample. Based upon the NYSDOH guidance, TCE and PCE were present soil vapor at concentrations below levels that require mitigation.

Chlorinated solvents are not associated with MGP operations, but are associated with other industrial activities such as metalworking and dry cleaning.

Indoor Air

Indoor air samples FW-IA-01 and FW-IA-02, were collected concurrently with soil vapor samples on July 31, 2008 and March 16, 2009. A duplicate indoor air sample of FW-IA-01 was collected during the March sampling event.

All indoor air VOC concentrations were below the 90th percentile BASE study concentrations with the exception of 2-butanone during the July 31, 2008 sampling (NYSDOH, 2006). 2-Butanone is commonly found as a solvent in paints and is also found in vehicle exhaust and is not related to the operation of the former MGP (Table 14). Trucks were stored overnight inside the warehouse as part of tenant operations at the time of sampling.

Based upon the NYSDOH guidance, TCE and PCE were present within indoor air at concentrations below levels that require mitigation.

Ambient (Outdoor) Air

All VOC concentrations were below the 90^{th} percentile of USEPA BASE study concentrations (Table 14).

A similar suite of compounds were noted within the outdoor air sample and the indoor air samples. The similar suite of compounds in the indoor and outdoor air samples is possibly attributed to the parking of trucks inside the building. Open garage doors were also used for ventilation and cooling in the building during the summer months. The warehouse is not equipped with a central air conditioning system.

SVI is not adversely affecting indoor air concentrations at the Parcel.

4.3.2 Parcel II

Soil Vapor

Two soil vapor samples were collected from a temporary soil vapor point (FW-SV-10) in the pool area of Thomas Greene Playground. Soil vapor sample FW-SV-10 was submitted to TestAmerica-Connecticut and a split sample (FW-SV-10-S) was submitted to Alpha. The soil vapor samples contained trace concentrations of VOCs (including chlorinated VOCs); however, naphthalene was not detected (Table 14). As previously discussed, chlorinated VOCs are not associated with the operation of the former Fulton MGP Site.

Helium trace gas was not detected in the soil vapor sample confirming that ambient air did not infiltrate into the soil vapor point and that the detected compounds were representative of subsurface conditions.

4.3.3 Parcel III

Sub-Slab Soil Vapor

Three sub-slab soil vapor points (FW-SV-05, FW-SV-06, and FW-SV-07) were installed to evaluate soil vapor conditions beneath the building on this parcel. The soil vapor tracer gas, helium, was detected at trace levels (0.16 % and 0.19%) within soil vapor samples. This indicated minimal infiltration through the soil vapor point seal at the time of sampling and that the soil vapor samples were representative of subsurface conditions.

Soil vapor samples collected from these points contained compounds that are common to MGP operations and petroleum products, including BTEX compounds. Naphthalene was detected at an estimated value of 1.6 micrograms per cubic meter (µg/m^3) in only one sample (FW-SV-05). Concentrations of compounds that are common to gasoline (n-octane, n-hexane and n-heptane) were also detected in each soil vapor sample.

Concentrations of a number of chlorinated solvents (TCE, PCE, chloroform, and cis-1,2 dichloroethene) were also detected in the soil vapor samples. Chlorinated solvents are not associated with MGP operations. Sub-slab soil vapor concentrations for chlorinated compounds ranged from 800 µg/m^{3}in FW-SV-05 to 180,000 µg/m^3 in a sample collected from FW-SV-07 (Table 14).

The highest concentrations of chlorinated VOCs were detected in FW-SV-07. This sample was collected within the footprint of the Majestic Metal Spinning & Stamping Company former spraying operations (on the Sanborn Maps from 1950 to 1982). It is likely that chlorinated solvents were used as part of the former Majestic Metal Spinning & Stamping Company operations.

Based upon the NYSDOH guidance, TCE, and PCE were present soil vapor at concentrations that require mitigation.

Indoor Air

Three indoor air samples (FW-IA-03, duplicate of FW-IA-03, and FW-IA-04) were collected inside the building. BTEX compounds and naphthalene were detected in indoor air samples at concentrations well below the 90 percentile of USEPA BASE study levels.

Concentrations of chlorinated solvents (TCE, 1,2-cis dichloroethene, and 1,4-dichlorobenzene) were detected above the 90th percentile USEPA BASE study levels (Table 14). TCE and 1, 2-cis dichloroethene are commonly used as degreasing agents in metal working industries and 1,4-dichlorobenzene is found in pesticides and used as a deodorant additive. TCE concentrations ranged from 17 to 40 µg/m^3, above the NYSDOH guideline of 5 µg/m^3. PCE concentrations ranged from 2.3to3.7µg/m^3, below the NYSDOH guideline of 100 µg/m^3, but above the matrix ratio of soil vapor to indoor air concentrations (Table 14).

Based upon the NYSDOH guidance, TCE and PCE were present in soil vapor and indoor air at concentrations that require mitigation.

Ambient (Outdoor) Air

One outdoor ambient air sample (FW-OA-02) was collected. All BTEX and chlorinated compounds were detected at concentrations well below outdoor background levels in the

USEPA BASE study, with the exception of methylene chloride (Table 14). Methylene chloride is a common solvent and is not related MGP operations. Low levels of VOCs in outdoor air are likely associated with the urban activity near the parcel.

4.3.4 Parcel IV

Soil Vapor

Two temporary soil vapor points (FW-SV-08 and FW-SV-09) were installed at the Parcel. FW-SV-08 was installed within the footprint of the former holder foundation and FW-SV-09 was installed approximately 95 feet, upgradient, to the east of the former holder foundation. A soil vapor sample was collected from FW-SV-08, and a soil vapor sample and a duplicate were collected from FW-SV-09.
Helium trace gas was not detected in the soil vapor samples confirming that ambient air did not infiltrate into the soil vapor point and that the detected compounds were representative of subsurface conditions.

BTEX and naphthalene were present in the soil vapor samples. These compounds are common to both petroleum products and to former MGP operations. However, other VOCs associated with gasoline, such as MTBE, n-decane, n-octane, and pentane, were also detected within the soil vapor samples (Table 14). MTBE is an indicator compound for gasoline. It is likely that these detected compounds in soil vapor on this parcel are related to post-MGP activities.

Concentrations of PCE, a chlorinated solvent, were also detected in each of the soil vapor sample locations. Chlorinated solvents are not associated with MGP operations.

Indoor Air

No building is located on Parcel IV; therefore, no indoor air samples were collected.

Ambient Outdoor Air

One ambient (outdoor) air sample (FW-OA-04) was collected at Parcel IV. VOCs were at levels below the 90^{th} percentile of the USEPA BASE study concentrations. Low levels of VOCs in outdoor air are likely associated with the urban activity near of the parcel. PCE is a chlorinated solvent and is not associated for MGP operations.

4.3.5 Parcel V

Sub-Slab Soil Vapor

Three soil vapor points (FW-SV-11, FW-SV-12 and FW-SV-13) were installed to evaluate soil vapor concentrations beneath the building. A soil vapor sample was collected from FW-

SV-11, FW-SV-12, and FW-SV-13. One blind duplicate soil vapor sample was collected from FW-SV-11.

Helium trace gas was not detected in the soil vapor sample confirming that ambient air did not infiltrate into the soil vapor point and that the detected compounds were representative of subsurface conditions.

Each soil vapor sample contained compounds that are common to petroleum products and to MGP residuals, including BTEX. Naphthalene was only detected in one of the three soil vapor samples.

Concentrations of chlorinated solvents including PCE and/or TCE were detected in each of the soil vapor samples. Chlorinated solvents are not associated with MGP operations.

Indoor Air

Four indoor air samples (FW-IA-05 through FW-IA-08) were collected to characterized indoor air concentrations. FW-IA-05 and FW-IA-06 were collected within the warehouse portion of building. FW-IA -07 and FW-IA-08 were collected within the rock climbing gym portion of the warehouse.

Toluene, ethyl benzene and xylene compounds were detected at concentrations above the 90^{th} percentile of USEPA BASE study concentrations and above the concentrations found within soil vapor.

Concentrations of TCE and PCE in indoor air were detected at levels below the 90^{th} percentile of the USEPA BASE study levels and the below DOH guidelines and below concentrations found in soil vapor.

A number of non MGP-related VOCs (ethanol, acetone, methylene chloride, 1, 2-dichloroethane, p-ethyltoluene, styrene –and n-decane) were detected above the USEPA BASE study background levels for indoor air. These VOCs were either not detected or detected at lower concentrations in soil vapor (Table 14). These VOCs are not associated with MGP operations. These compounds are found in commonly used chemical products, paints, petroleum distillates and plastic-based products which were stored and used during the renovation of the rock climbing gym portion of the building shortly before the indoor air sampling occurred.

Ambient (Outdoor) Air

One outdoor ambient air sample (FW-OA-03) was collected from Parcel V. All of the detected compounds were well below outdoor background levels in the 90^{th} percentile of the

USEPA BASE study, with the exception of methylene chloride, a chlorinated solvent not associated with MGP operations.

4.4 NAPL

DNAPL tar was observed in a number of borings completed within and adjacent to former gas holders located at Parcels II, III and IV, the gas production area at Parcel I and in borings within adjacent street ROWs. DNAPL tar saturated layers were observed in soil borings completed adjacent to the eastern and western bulkhead of the Gowanus Canal at depths below the bottom of the Canal floor.

Discrete blebs of petroleum-related LNAPL (exhibiting petroleum odors) were observed in monitoring wells FW-MW-03, FW-MW-03R and FW-MW-01R in the sidewalk adjacent to Parcel I. No measureable LNAPL was observed in the wells. The monitoring wells are screened across soils that exhibited staining, sheens and petroleum-like odors.

DNAPL tar was observed in three monitoring wells located adjacent to Thomas Greene Playground as follows:

- DNAPL exhibiting tar odor was observed at wells KSF-MW-6 and KSF-MW-7 during groundwater sampling during the NYSDEC's SC in 2007. However, DNAPL was not observed in subsequent gauging events in 2009 and 2011.

- Discrete tar blebs were observed during the gauging of KSF-MW-02 in 2010 and 2011. No measureable amount of DNAPL was observed in the well.

DNAPL tar was observed in two monitoring wells adjacent to the western bulkhead of the Gowanus Canal, as follows:

- Discrete blebs of tar were observed on the bottom of the measuring tape during gauging of GC-MW34I.
- Tar staining was observed on the groundwater sampling tubing for FW-MW-22I.

5. Fate and Transport

This section provides includes analysis and discussion of the data presented in previous sections, interpreting the interaction between the physical and chemical processes at the Site. Through an understanding of sources, migration pathways, and potential receptors, the potential need for remedial actions to protect human health and/or the environment can be evaluated.

The following analysis takes into account the physical characteristics and surroundings of the RI study area, the groundwater hydrology, history, the nature of the chemical compounds encountered during the sampling and analysis programs, and any apparent trends in the distribution of these materials on or adjacent to the RI study area. This section provides a discussion of the physical, chemical, and biological characteristics of COPCs, and a discussion of the sources, migration pathways, and receptors for those COPCs associated with the RI study area. COPCs are defined as those constituents that are present within each media at concentrations exceeding the Unrestricted Use SCOs and generally include VOCs, SVOCs, pesticides, PCBs, and metals.

The environmental media that may serve as pathways for COPC migration are NAPL, surface soil, subsurface soil, groundwater, and soil vapor.

5.1 NAPL

NAPL fate and transport is dependent on various characteristics of the NAPL and of the media in which the NAPL is present. For a NAPL to be potentially mobile in a porous media, the NAPL must be present in a fully saturated state. However, the flow paths along which these fully saturated conditions exist can result in a complex “architecture” (or pattern/distribution) of NAPL and residual impacts. Fully saturated conditions consist of accumulations where the entirety of the pore space of the media is filled with NAPL, creating continuous liquid phase in the pore spaces (Guswa, 2003). The saturated conditions result in a NAPL head pressure within the media and serve as the driving force on the NAPL. The relative mobility of NAPL in the saturated zone is dependent on the density and the viscosity of the NAPL, as well as the grain size of the soil media. Light NAPLs (LNAPLs), with a density less than water, will tend to float on the surface of the water table while DNAPLs, with a density greater than water, will sink below the water table. The viscosity of the NAPL, or the measure of a NAPLs’ resistance to flow, has a similar effect on the relative mobility. A NAPL with a high viscosity will be resistant to flow while a NAPL with a low viscosity will flow more readily. Finally, the more permeable the soil media, the more likely tar will migrate in it. Tar, a DNAPL, with a viscosity higher than water and a density greater than water, will have a tendency to penetrate the water table readily (USEPA, 1992).

Once in contact with groundwater in a porous media, the interfacial tensions and wetability of the DNAPL, along with the DNAPL head pressure, dictate further vertical migration. In most natural systems, water is the wetting fluid and the DNAPL is the non-wetting fluid. The wetting fluid will tend to coat the surface of the grains and occupy the smaller pore spaces, where the non-wetting fluid will tend to be restricted the largest openings. Therefore, a DNAPL with a low interfacial tension with water, like tar, would typically be the non-wetting fluid and would be restricted to the larger pore spaces in the media.

The characteristics of the media (capillary force/pressures, pore size distribution, moisture content, and stratigraphic changes) in conjunction with the DNAPL characteristics described above, determine whether and how DNAPL tar will move in a porous media.

Before a non-wetting fluid such as DNAPL tar, can enter a porous media, the entry pressure of the DNAPL must exceed the capillary pressures of the largest pores. The entry pressure is achieved when a sufficient volume of DNAPL, typically at full saturation, creates a DNAPL pressure head (driving force), which exceeds the entry pressure. Even when the entry pressure is achieved, the DNAPL migration is still typically restricted to the larger pore spaces and does not displace the water from the smaller pore spaces typical of fine-grained materials like silt and clay.

As a finite volume of a DNAPL migrates through a porous media, the volume of DNAPL becomes spread until the DNAPL is no longer in a saturated state. When NAPL is not present in a saturated state, it is said to be in a residual state typically consisting of discrete blebs. Material in a residual state no longer has sufficient volume to create the pressure head needed to overcome the entry pressure of the porous media (Guswa, 2003) and the migration front thus stagnates unless acted upon by an outside force.

DNAPL tar was observed in several borings and discrete tar blebs were observed in the water column of three monitoring wells (KSF-MW-02, FW-MW-22I, and GCMW-34I). Cross-sections A-A′ through E-E′ (Figures 11 and 12) depict physical observations of NAPL at each boring shown. These cross-sections can be used to interpret the vertical and lateral extent of DNAPL tar impacts. Figure 13 depicts the extent of impacts between elevations of 0 feet and -25 feet.

The majority of the DNAPL tar impacts are present east of the canal, beneath Parcels I, II, III, IV, and VI, and in proximity to the eastern and western bulkheads of the canal, as discussed below. Petroleum NAPL is present beneath Parcel I (above the meadow mat) with deeper tar impacts.

5.1.1 Parcel I

Soils stained and coated with petroleum were observed in soils at Parcel I. The parcel previously contained a 100,000-gallon oil/naphtha tank and was the location of oil pumps for the MGP as well as petroleum storage for post MGP operations.

Petroleum-impacted soils were encountered at the water table and as deep as 32 feet bgs. No measurable LNAPL was observed in monitoring wells at the Site. However, discrete blebs of grease-like LNAPL were observed in FW-MW-03 and FW-MW-1R during the groundwater sampling in September 2009.

The1915 Sanborn historical maps depict the presence of underground tar and oil tanks with overflow pipes (1897 BUG drawing) leading to the canal. The shallow subsurface impacts are consistent with the former presence of oil tanks and the deeper tar impacts are consistent with the former presence of a tar/water separator, as well as potential migration from the canal sediments to the land.

The sediment surface elevation at GC-SD108 is -4.2 feet NAVD88, and tar impacts were observed at elevation -17. The closest soil boring in Parcel I is FW-SB-05B. Tar coatings were present in this soil boring from elevation 3.01 to elevation-11.99. The higher elevation of tar on the landside relative to tar impacts in the canal suggests there has been some subsurface migration from the landside into the sediments over time.

The closest landside boring to GC-SED-09B is GC-GP-06. The elevation of the first tar-related impacts in GC-GP-06 was -29.34. Tar impacts in GC-SED-09B were at -9.53, significantly shallower. These data suggest that some tar may have migrated toward the landside. The same relationship is apparent between GC-SED-08 and GC-GP-06.

5.1.2 Parcel II and Adjacent Street ROWs

Tar impacts were encountered beneath the swimming pool/handball court area of Parcel II and within the adjacent Nevins and Degraw Street ROWs. The shallowest impacts beneath the pool are approximately 8 feet deeper than the pool itself. Tar impacts were primarily found next to the former holder and unknown tanks in the current swimming pool area. Tar impacts were encountered within fill above the less permeable meadow mat deposits. Tar appears to have migrated downward through the meadow mat deposits into the glacial outwash sands. A portion of the tar appears to have migrated laterally to the west atop the meadow mat beneath Parcel II into Nevins Street (FW-SB-29) and Degraw Street (FW-SB-35) where the meadow mat was not encountered (Cross-section E-E', Plate 12). A portion of the tar appears to have migrated in the fill and atop the meadow mat to Parcel III, which is discussed below in subsection 5.1.2. The majority of the tar impacts beneath Parcel II and in

Degraw Street (FW-SB-35) and Nevins Street (FW-SB-29) were present at elevation -12 feet and deeper, at a level below the bottom of the Gowanus Canal, where exposure is unlikely.

The tar migrated downward and collected on less permeable silt-sand layers that are sporadically distributed in the glacial outwash. These less permeable lenses likely caused a portion of the tar to migrate laterally to the north beneath Douglass Street and eastward beneath the Playground Area at Parcel II, thus further decreasing the volume of tar contributing to the downward mobility of the DNAPL front. As the tar migrated downward, the volume of tar was spread (left behind) in a residual traces. The amount of tar impacts decreased in frequency with depth until the pressure head was insufficient to allow the continued downward migration of the DNAPL front.

5.1.3 Parcel III and Parcel IV

Tar saturation, tar saturated lenses and tar coated soils were encountered within the former holder foundation at Parcel III. A limited amount of residual petroleum and tar impacts (staining and coated soils) were encountered within soil borings KSF-SB-20 (Parcel IV), KSF-SB-21, KSF-SB-22, and FW-SB-10 within the Degraw Street ROW. It appears that tar from Parcel II migrated laterally to these boring locations in the fill atop the meadow mat to the west.

5.1.4 Parcel VI

Parcel VI was not part of the former Fulton MGP. Boring KSF-SB-14, FW-SB-29, and FW-SB-35 all contained DNAPL at various depths, and to a maximum depth of 128 feet bgs. The deepest subsurface impacts are believed to have migrated there from upgradient locations. Shallower tar impacts may be due to migration from adjacent parcels.

5.1.5 Borings Adjacent to Gowanus Canal Bulkheads

Tar saturated soils and inter-bedded lenses of tar saturation were encountered in soil borings located adjacent to the eastern and western bulkheads of the Gowanus Canal. Tar impacts were encountered as shallow as elevation -12.77 feet in FW-SB-49 within Sackett Street west of the canal (Figure 11). Along the eastern bulkhead, the shallowest tar saturated soils were encountered at elevation -3.1 feet (FW-SB-05B).

Tar impacts were encountered in sediment cores within native sediments completed within the Gowanus Canal adjacent to the Fulton MGP. Native sediments contained tar coated soils and tar saturated lenses at an elevation of approximately -15 feet in GC-SED-08 and -10 feet in GC-SED-09B within the Gowanus Canal adjacent to Parcel I. A petroleum coating was also observed in native sediments at elevation -10.8 to -11.2 feet and elevation -14.5 to -15.5 feet in GC-SED-152.

Tar is sometimes present at higher elevations in the Gowanus Canal than to the east, near source areas at the MGP. Tar is also present in the canal adjacent to Parcel VII, where no tar has been observed on the landside.

Tar in the sediments likely spread laterally beneath the eastern and western bulkheads, accounting for the shallow tar impacts adjacent to both sides of the Canal (Figures 11 and 12).

Borings GCMW-03I and GC-MW34, on the west side of the canal, encountered soils saturated with low viscosity petroleum hydrocarbons (LNAPL) at elevations starting at approximately -13 feet and -17 feet. These petroleum impacts may be related to the former Bayside Fuel Oil Depot; a more recent bulk petroleum storage and transport facility not associated with the former MGP operations.

5.2 Surface Soil

SVOCs (PAHs and 4-methylphenol), pesticides, PCBs and metals were identified as COPCs in surface soils. VOCs (including BTEX compounds), herbicides, and cyanide were not detected above the Unrestricted SCOs and; therefore, are not considered COPCs for surface soils.

The former Fulton MGP Site is primarily covered by bituminous asphalt, concrete sidewalks, and buildings. However, Parcel IV is unpaved and portions of Parcels I, II, and III are unpaved.

PAHs, pesticides, PCBs, and metals could potentially migrate via fugitive dust emissions and dissolution into surface water run-off. Each of these pathways and its potential to occur at the Site are described below:

- **Fugitive Dust.** COPCs sorbed to soil particulates could be transported as fugitive dust if exposed to wind erosion. PAHs exhibit varying degrees of binding affinity to organic matter and soil particles; this affinity is partly dependent upon their individual molecular structures. In general, the higher the molecular weight in PAHs (e.g., BAP), the more strongly they are sorbed, whereas the lighter PAHs (e.g., naphthalene) are less strongly sorbed (USEPA, 1979; USEPA, 1986). Therefore, the higher molecular weight in PAHs are expected to remain sorbed to soils, while the lighter-end PAHs may be desorbed and transported by other mechanisms. Metals also generally exhibit an affinity to particulates. The unvegetated areas may be prone to wind erosion and the transport of COPCs sorbed to the dust generated by wind action.

- **Solubility.** This is the measure of a chemical's ability to dissolve in water. COPCs sorbed to surface soil may dissolve in water and may be transported as surface water, which then infiltrates into the ground or runs-off the Site. PAHs have a varying degree of solubility. The lighter-end PAHs are more soluble while the heavier-end PAHs are less soluble and typically do not dissolve into water. PCBs are also generally insoluble and will also not dissolve into water. The dissolution of metals typically occurs in reducing conditions which are unlikely to occur in surface soils. Given the nature of the compounds in the surface soil, dissolution of compounds in surface water is likely not a major migration pathway.

Migration of COPCs from the surface soil is possible at the Site, but primarily through the transport of particulates. The nature of the COPCs is such that they are relatively persistent in soils and would likely remain attached to soil particulates. Potential exposure pathways to impacted surface soils are evaluated below in the QHHEA in Section 6.

5.3 Subsurface Soil

VOCs (BTEX, chlorinated compounds, and acetone), SVOC (PAHs and dibenzofuran), PCBs, pesticides, and metals were identified as COPCs in subsurface soil. In general, the distribution of BTEX and PAHs in soil coincides with the presence of tar. Section 4 discusses the extent of COPCs (BTEX and PAHs) associated with the presence of tar and petroleum. Section 4 also discusses the nature and extent of chlorinated VOCs, pesticides, and PCBs.

The COPCs could potentially migrate through subsurface soil by volatilization, sorption, and solubility. Each migration pathway, as it relates to the COPCs identified in subsurface soil at the Site, is discussed below:

- **Volatilization**. VOCs constituents are volatile and, therefore, may be transported from subsurface soils, tar, petroleum-impacted soils and groundwater to soil gas in the vadose zone and then into ambient air. PAHs, pesticides, PCBs, and metals do not readily volatilize; therefore, they are not COPCs for soil vapor. BTEX compounds detected in soil gas have not adversely impacted indoor air quality. Chlorinated VOCs are present in soil vapor and have impacted the air quality at Parcel III.

- **Sorption**. This is usually defined as the reversible binding of a chemical to a solid matrix. However, there is evidence in the published literature that there is a partially irreversible component related to the time that the compound has been sorbed to a soil matrix (Brusseau, et al., 1989; Brusseau, et al., 1991; Loehr, et al., 1996). Sorption of BTEX, PAHs, and metals limits the fraction available for other fate processes such as volatilization and/or solubility. In general, BTEX compounds have low sorption potential, coupled with high water solubility and high volatility, which make sorption a relatively minor environmental fate process for BTEX compared to other mechanisms. PAHs exhibit varying degrees of binding affinity to organic matter and soil particles; this affinity is dependent upon their individual molecular structures. In general, the higher molecular weight in PAHs (e.g., benzo(a)pyrene), the more strongly they are sorbed, whereas the lighter PAHs (e.g., naphthalene) are less strongly sorbed (USEPA, 1979; USEPA, 1986). Therefore, the higher molecular weight PAHs are expected to remain sorbed to soils, while the lighter-end PAHs may be desorbed and transported by other mechanisms. Metals may remain sorbed to the subsurface soils depending on subsurface oxidation-reduction conditions and the availability of anions that the metals could bind with. Pesticides adhere and remain sorbed to organic matter within soil. Metals and pesticides that do not remain sorbed to subsurface soils could be available for transport through the groundwater system in solution (see below).

- **Solubility**. BTEX and chlorinated VOCs have a relatively high solubility. Since tar was encountered below the water table, and BTEX and lighter-end PAHs are COPCs in subsurface soil, dissolution of these COPCs from soil to groundwater represents a migration pathway at the RI study area.

Soils in the intermediate and deep groundwater zone that are in contact with tar will also be subject to BTEX and lighter-end PAH dissolution.

Metals in the subsurface soils could dissolve and continue to leach to the groundwater system. However, the solubility of metals is highly dependent upon the oxidation-reduction conditions of the aquifer, the valance state of the specific metal, and the availability of anions that the metals could bind with to become immobile. Dissolution of metals in the subsurface soils and transport in the dissolved state through the groundwater system is not considered to be a major transport mechanism because only naturally occurring metals (i.e. magnesium, manganese, and sodium) were detected.

In summary, the presence of tar and petroleum at the Site will likely result in the persistent presence of BTEX and PAHs in groundwater downgradient of the tar extent. BTEX constituents in subsurface soils not associated with tar are typically mobile and are not particularly persistent in the surrounding environment due to their high volatility, low adsorption to soils, and high water solubility. With few exceptions, the PAHs associated with the Site will be relatively persistent in the soil matrix and will be associated with tar. This is primarily due to their generally low water solubility and high sorption to soils. Metals in soil are also anticipated to be relatively persistent. Potential exposure pathways to impacted subsurface soils are evaluated below in the QHHEA in Section 6.

5.4 Groundwater

VOCs (BTEX, MTBE and chlorinated VOCs), PAHs, pesticides, and cyanide have been identified as COPCs in groundwater.

Iron, magnesium, manganese, and sodium were also detected in groundwater at levels exceeding the NYSAWQSs. However, many of these inorganic substances are naturally occurring and are representative of background conditions.

The fate and transport migration pathways for COPCs in groundwater are determined by volatilization, sorption, and solubility as described above in subsurface soils. Dissolved phase shallow groundwater impacts (BTEX and light-end PAHs) are present within and downgradient of areas where tar was observed in subsurface soils in the RI study area. BTEX, MTBE, and light-end PAHs are also present within petroleum-impacted soils (Figures 11 to 13). Total cyanide was present at Parcel III, where gas-purifying activities took place and at Parcel IV. Chlorinated VOCs were present in monitoring wells located in the Sackett Street ROW downgradient of Parcel III.

BTEX and light-end PAHs will continue to desorb as groundwater flows through soils with tar, petroleum and chlorinated VOC impacts. Refer to Figure 14 and 15 for BTEX, PAH, and cyanide concentrations and groundwater contours. To the east of the Gowanus Canal, shallow groundwater generally flows from FW-MW-19 and FW-MW-14 west to southwest toward the Canal. Shallow groundwater on the west side of the Gowanus Canal flows to the east and south toward the Canal. Groundwater flows toward the Gowanus Canal at high and low tides.

Groundwater in the intermediate groundwater zone of the Upper Glacial Aquifer generally flows toward the Gowanus Canal and converges on a southerly flow path in the vicinity of Parcel I, just to the east of the Canal. Dissolved groundwater impacts will be transported in the direction of groundwater flow with some upward transport from the intermediate groundwater zone to the water table portion of the Upper Glacial Aquifer.

Based upon the calculated linear flow velocities, discharge from the shallow and intermediate zone to the Gowanus Canal is limited. Groundwater concentrations that discharge to the Gowanus Canal may be mitigated by volatilization, biodegradation, and dilution mechanisms. Potential exposure pathways to impacted groundwater are evaluated below in the QHHEA in Section 6.

Groundwater in the deep zone of the Upper Glacial Aquifer and Jameco Aquifer are expected to flow southward based on regional flow patterns. Very low levels of dissolved phase impacts were observed in these zones, and transport of contaminants in these zones is expected to be negligible.

5.5 Soil Vapor

VOCs (including BTEX, naphthalene, and chlorinated compounds) were detected within soil vapor, unsaturated subsurface soils and in groundwater. The VOCs could be transported from subsurface soils and shallow groundwater to the soil vapor in the vadose zone and then into ambient air where concentrations would be mitigated by dilution. The Site and surrounding area are primarily covered by pavement and building which would limit volatilization into ambient air. Detections of COPCs in ambient (outdoor) air were below levels found in the BASE study with the exception of methylene chloride in FW-OA-02 at Parcel III. Methylene chloride is a chlorinated solvent not associated with MGP operations. Aerobic degradation of aromatic hydrocarbons (e.g. BTEX) in the vadose zone has been widely demonstrated and essentially eliminates the potential for these VOCs to cause adverse indoor air impacts unless the sources of the VOCs are in direct communication with the indoor building space. Chlorinated VOCs (unassociated with the former MGP) pose a potential to migrate to indoor air as they are not subject to aerobic degradation in the vadose zone.

SVI analysis sampling of soil vapor indoor air within buildings at Parcels I, III and V demonstrates that concentrations of BTEX and naphthalene in soil vapor present at concentrations within the range of BASE concentrations. MGP compounds are not adversely affecting indoor air quality.

However, chlorinated solvents (PCE and TCE) concentrations in the soil vapor have impacted indoor air. TCE concentrations were above the 90^{th} percentile of the USEPA BASE Study values. Potential exposure pathways are evaluated below in the QHHEA in Section 6.

6. Qualitative Human Health Exposure Assessment (QHHEA)

This section addresses the qualitative exposures potentially posed to human receptors by COPCs that are present in surface soil, subsurface soil, and groundwater at concentrations in excess of the Unrestricted Use SCOs and NYSAWQS. This conservative comparison to Unrestricted Use SCOs is presented at the request of NYSDEC and NYSDOH. The results are also evaluated with respect to the Commercial Use SCOs. The latter approach is more appropriate given the current manufacturing zoned use of the Site and surrounding area. It should be noted that all COPCs exceeding these thresholds are evaluated regardless of whether a particular COPC is related to the former MGP operation or not. For example, PCBs and chlorinated solvents are included as COPCs for this QHHEA even though these compounds either were not synthesized or broadly used during the era of the MGP operation.

Tables 11, 12, 13, and 14 provide a summary of the detected concentrations and highlights compounds that are above criteria values in surface soil, subsurface soil, groundwater, soil vapor and indoor ambient air.

6.1 Exposure Pathways

An exposure pathway describes the means by which a potential receptor may be exposed to contaminants originating from a site. Assessment of potential exposure pathways includes the following five elements (NYSDEC, 2010):

(1) A contaminant source
(2) Contaminant release and transport mechanisms
(3) A point of exposure
(4) A route of exposure
(5) A receptor population

The NYSDEC and NYSDOH consider an exposure pathway complete when all five elements of an exposure pathway are documented. An exposure pathway may be eliminated from further evaluation when any one of the five elements comprising an exposure pathway has not existed in the past, does not exist in the present, and will never exist in the future (NYSDEC, 2010).

Sections 4 and 5 of this report document the source of the COPCs (element 1), the nature of the contaminants, and the transport mechanisms that account for the distribution of COPCs (element 2). This information is then used to present a summary of complete exposure pathways. The qualitative exposure assessment summarizes the COPCs at the study area (elements 1 and 2), the media in which COPCs are present (potential exposure points; element 3), the potential exposure routes of the COPCs (i.e., ingestion, inhalation, dermal absorption; element 4), and the assumed potential receptors (element 5).

It is important to note that this QHHEA assumes that contaminant conditions have not or will not be mitigated. In this sense, a “baseline” of potential exposures is presented. This evaluation was conducted in accordance with Appendix 3B of the *DER-10 Technical Guidance for Site Investigation and Remediation* (NYSDEC, 2010), which summarizes the approach for preparing a qualitative human health exposure assessment.

For the purposes of this assessment, it is assumed that future land uses of the RI study area will remain zoned for manufacturing uses.

6.2 Surface Soils

The following compounds were detected above the Unrestricted Use SCOs:

SVOCs	Benz[a]anthracene Benzo[a]pyrene Benzo[b]fluoranthene Benzo[g,h,i]perylene Benzo[k]fluoranthene Chrysene Dibenz[a,h]anthracene Indeno[1,2,3-cd]pyrene 4-Methylphenol (p-Cresol)
Pesticides	Aldrin 4,4-DDD 4,4-DDE 4,4-DDT Dieldrin
PCBs	
Metals	Cadmium Copper Lead Mercury Nickel Zinc

Potentially complete exposure pathways exist for these compounds in surface soils. The potential pathways are ingestion, dermal contact, and inhalation. The potential receptors include the Adult and Child Visitor, Adult Commercial Worker and Adult Utility Worker under current and future expected use.

6.3 Subsurface Soils

The following compounds were detected above the Unrestricted Use SCOs in subsurface soils:

VOCs	Benzene Toluene Ethylbenzene Xylene Acetone cis-1,2-Dichloroethene trans-1,2-dichloroethene Methylene chloride TCE PVC 2-Butanone
SVOCs	Acenaphthene Acenaphthylene Anthracene Benz[a]anthracene Benzo[a]pyrene Benzo[b]fluoranthene Benzo[g,h,i]perylene Benzo[k]fluoranthene Chrysene Dibenz[a,h]anthracene Fluoranthene Fluorene Indeno[1,2,3-cd]pyrene Naphthalene Phenanthrene Pyrene Dibenzofuran
Pesticides	Aldrin alpha-BHC Beta-BHC 4,4-DDD 4,4-DDE 4,4-DDT Endrin Dieldrin Heptachlor
Metals	Arsenic Barium Cadmium Copper Lead Mercury Nickel Silver Zinc

Potentially complete exposure pathways exist for these compounds in subsurface soils. The potential pathways are ingestion, dermal contact, and inhalation. The potential receptors include Adult Commercial Worker and Utility Worker under current and future expected use.

6.4 Groundwater

Potentially complete exposure pathways exist for groundwater via ingestion, dermal contact, and inhalation for the Adult Commercial Worker and the Adult Utility Worker for the following compounds:

VOCs	Benzene Toluene Ethylbenzene Xylene Acetone Chloroethane Chloroform cis-1,2-Dichloroethene Isopropyl benzene MTBE Methylene chloride Styrene PCE TCE PVC
SVOCs	Acenaphthene Acenaphthylene Anthracene Benz[a]anthracene Benzo[a]pyrene Benzo[b]fluoranthene Benzo[k]fluoranthene Chrysene Fluorene Indeno[1,2,3-cd]pyrene Naphthalene Phenanthrene 1,1-Biphenyl 2-Methylphenol (o-Cresol) 4-Methylphenol (p-Cresol) Phenol
Pesticides	alpha-BHC Beta-BHC Gamma-BHC Delta-BHC Dieldrin Heptachlor Heptachlor epoxide

Metals	Arsenic Barium Beryllium Chromium Copper Iron Lead Magnesium Manganese Mercury Nickel Sodium Thallium
Other	Cyanide Sulfate Chloride Ammonia

However, these potentially complete exposure pathways must be triggered by intrusive subsurface activity, such as excavation. To the east of the Gowanus Canal adjacent to the former Fulton MGP Site, groundwater was encountered from 3.86 feet bgs (KSF-MW-6) to 17.39 feet bgs (FW-MW-13) which limits the potential for contact. In addition, iron, magnesium, manganese, sodium, and thallium detected in the groundwater at the Site are frequently naturally occurring compounds.

6.5 Soil Vapor

A potentially complete exposure pathway to organic compounds in soil vapor exists for Adult Utility and Construction Workers if intrusive activity such as soil excavation at Parcels I through V is conducted. However, these soil vapor concentrations are significantly below Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs) for occupational workers. The building foundations provide physical barriers that limit vapor intrusion into the buildings at Parcels I, III, and V.

6.6 Indoor Air

Former MGP operations do not appear to be the source of VOCs impacting the indoor air quality at on the former Fulton MGP Site and in the RI study area.

Concentrations of compounds found in the indoor air on the building located on Parcel I were similar to compounds found in the outdoor air sample. The similarity between these samples may be attributed to the use of garage doors for ventilation and moving vehicles into and out of the building.

In the building located on Parcel III, chlorinated compounds (TCE and PCE) are present in the soil vapor and indoor air at concentrations that trigger mitigation, according to the NYSDOH Soil Vapor Decision Matrices. As previously discussed, these compounds are not related to MGP operations and are likely related to the Majestic Metal Spinning and Stamping Company former spraying operations. A potentially complete exposure pathway to these compounds exists for Adult and Child Visitor, Adult Commercial Worker and Adult Utility Worker.

Analysis of indoor air in the building on Parcel V detected a number of non MGP-related VOCs, ethanol, acetone, methylene chloride, 1, 2-dichloroethane, p-ethyltoluene, styrene, and n-decane, at concentrations above background levels. These VOCs were either not detected or detected at much lower concentrations in soil vapor. These compounds are found in commonly used chemical products, paints, petroleum distillates and plastic-based products and are likely related to the products stored and used during the renovation of the building. A potentially complete exposure pathway to these compounds exists for Adult and Child Visitor, Adult Commercial Worker, and Adult Utility Worker.

6.7 QHHEA Discussion

The QHHEA has revealed that there are potentially complete exposure pathways to surface and subsurface soils above the Unrestricted Use SCOs, groundwater above the NYSAWQSs, soil vapor above background conditions, and indoor air above background and NYSDOH Action Levels.

6.7.1 Summary of Potential Exposure Pathways

A summary of the media of concern and potential receptors based on soil Commercial Use SCOs for soil, NYSAWQSs for groundwater and 90th percentile of the USEPA BASE and is presented in the following table. Potential receptors are based on current site use and adjacent sites uses, and the potential for future uses and activities (i.e., construction/utility activities). Potentially complete exposure pathways are identified if a receptor has a current or potential future exposure to impacted media.

Parcel ID	Media of Concern	Exposure Routes	Construction/ Utility Worker	Adult/Child Visitor	Trespasser
Parcel I	Surface Soil	Inhalation (particulates) Direct contact Ingestion	√	√	√
	Subsurface Soil	Direct Contact Ingestion Inhalation (particulates)	√	--	--
	Groundwater	Ingestion Direct Contact	√	--	--
	Soil Vapor	Inhalation	√	--	--
	Indoor Air	Inhalation	√	√	√
Parcel II	Surface Soil	Inhalation (particulates) Direct contact Ingestion	√	√	√
	Subsurface Soil	Direct Contact Ingestion Inhalation (particulates)	√	--	--
	Groundwater	Ingestion Direct Contact	√	--	--
	Soil Vapor	Inhalation	√	--	--
Parcel III	Surface Soil	Inhalation (particulates) Direct contact Ingestion	√	√	√
	Subsurface Soil	Direct Contact Ingestion Inhalation (particulates)	√	--	--
	Groundwater	Ingestion Direct Contact	√	--	--
	Soil Vapor	Inhalation	√	--	--
	Indoor Air	Inhalation	√	√	√
Parcel IV	Surface Soil	Inhalation (particulates) Direct contact Ingestion	√	√	√
	Subsurface Soil	Direct Contact Ingestion Inhalation (particulates)	√	--	--
	Groundwater	Ingestion Direct Contact	√	--	--
	Soil Vapor	Inhalation	√	--	--

Parcel ID	Media of Concern	Exposure Routes	Construction/ Utility Worker	Adult/Child Visitor	Trespasser
Parcel V	Surface Soil	Inhalation (particulates) Direct contact Ingestion	√	--	--
	Subsurface Soil	Direct Contact Ingestion Inhalation (particulates)	√	--	--
	Groundwater	Ingestion Direct Contact	√	--	--
	Soil Vapor	Inhalation	√	--	--
	Indoor Air	Inhalation	√	√	√
Parcel VI	Surface Soil	Inhalation (particulates) Direct contact Ingestion	√	√	√
	Subsurface Soil	Direct Contact Ingestion Inhalation (particulates)	√	--	--
	Groundwater	Ingestion Direct Contact	√	--	--
Parcel VII	Subsurface Soil	Direct Contact Ingestion Inhalation (particulates)	√	--	--
	Groundwater	Ingestion Direct Contact	√	--	--
Street ROWs Adjacent to Fulton MGP Site	Surface Soil	Inhalation (particulates) Direct contact Ingestion	√	√	√
	Subsurface Soil	Direct Contact Ingestion Inhalation (particulates)	√	--	--
	Groundwater	Ingestion Direct Contact	√	--	--

Based on the table above, the potentially complete exposure pathways follow:

- Inhalation of dust and vapors by an Adult/Child, trespasser and Construction/utility worker.
- Accidental ingestion and/or direct contact with surface soil by an Adult/Child, Trespasser, and Construction/utility worker.

- Accidental ingestion and/or direct contact with subsurface soil by a construction/utility worker.
- Accidental ingestion and/or direct contact with groundwater by a construction/utility worker.

The following subsections describe the rationale for establishing potentially complete exposure pathways at this Site.

However, the former Fulton MGP Site and RI study area are zoned for manufacturing use. This use is expected to continue in the future. Based on the current and future use of the former Fulton MGP Site and the RI study area, a comparison to the Commercial Use SCO is appropriate. When comparing the concentrations of chemicals detected in this RI to the Commercial Use SCOs, the number of potentially complete exposure pathways are reduced, as follows.

6.7.2 Surface soils

Potentially complete exposure pathways to a number of SVOCs, all pesticides, PCBs and metals are eliminated when compared to the Commercial Use SCOs as discussed below.

Potentially complete exposure pathways exists for only five PAH compounds, benz[a]anthracene, BAP, benzo[b]fluoranthene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene at one surface soil sample location (FW-SS-08) at Parcel II when compared to the Commercial Use SCOs. Surface soil sample (FW-SS-08) was collected within a tree planter outside the footprint of MGP operations in an area that was previous used as a pipe lay down area. The exposed surface soils likely represent imported historic fill material around the trees. Historic fill was encountered in deeper intervals at borehole locations within the Park during the RI soil investigations and also during the SC investigations. Because of the limited areas of exposed surface soils and infrequent contact, surface soil PAHs do not pose a substantive exposure concern at the Park.

A potentially complete exposure pathway to BAP is present in four additional samples.

- FW-SS-01 [Parcel I]
- FW-SS-05 and FW-SS-09 [Parcel II]
- FW-SS-04 [Parcel IV]
- FW-DSS-03 [Parcel VI]

PAHs (including BAP) were also detected in surface soils off site. This indicates that PAHs in surface soils are present as a function of the urban conditions, not former MGP operations.

6.7.3 Subsurface Soils

There were 47 compounds in subsurface soil with concentrations higher than the Unrestricted Use SCOs. The number of compounds is reduced to 27 compounds when compared to the Commercial Use SCOs which eliminates potentially complete exposure pathways to a number of SVOCs, metals and all pesticides and PCBs. A potentially complete exposure pathway exists for concentrations above the Commercial Use SCOs for:

VOCs	Benzene Toluene Ethylbenzene Xylene
SVOCs	Acenaphthene Acenaphthylene Anthracene Benz[a]anthracene BAP Benzo[b]fluoranthene Benzo[g,h,i]perylene Benzo[k]fluoranthene Chrysene Dibenz[a,h]anthracene Fluoranthene Fluorene Indeno[1,2,3-cd]pyrene Naphthalene Phenanthrene Pyrene
Metals	Arsenic Barium Lead Mercury

Most of the exceedances were encountered at depth (Table 2, 3 and 13). As previously discussed, the majority of the former Fulton MGP Site and the RI study area is either paved or covered with buildings. Parcel I, a small portion of Parcel III, Parcel IV, and Parcel VI contain areas that are unpaved. The unpaved area at Parcel I is covered with approximately 6 inches of gravel which limits potential exposure. Parcel III and IV have gates that are secured which limit access to the properties. Parcel I is fenced and contained Mercury and barium that are metals that are not typically associated with MGP operations.

6.7.4 Groundwater

Potentially complete exposure pathways to VOCs, SVOCs, metals, and cyanide compounds exist for groundwater via ingestion, dermal contact, and inhalation at the Site for the Adult Commercial Worker and Adult Utility Worker. However, these potentially complete exposure pathways must be triggered by intrusive subsurface activity, such as excavation.

Groundwater at the Site is approximately 4 and 13 feet below grade limiting the potential for contact. The RI study area is developed with buildings and the majority of the area is paved further reducing the potential for intrusive activities.

In addition, iron, magnesium, manganese, sodium, and thallium detected in the groundwater at the Site are frequently naturally occurring compounds.

6.7.5 Soil Vapor

In the event that soils are disturbed, a potentially complete exposure pathway to organic compounds via inhalation in soil vapor may exist for the utility and construction worker. As discussed above, the majority of the MGP Site and RI study area is paved. Dilution and dispersion of soil vapor migrating from soil to air greatly reduces the concentrations of vapors, minimizing human health exposures. Concentrations of VOCs are significantly less than the OSHA PELs for occupational workers. Although these concentrations in soil vapor are slightly higher than some of the background indoor air concentrations, the buildings are physical barriers that greatly reduce the potential for vapor intrusion. As such, soil vapor does not appear to be a realistic risk at the Site.

6.7.6 Indoor Air

Concentrations of VOCs were detected above background indoor air concentrations and TCE, a chlorinated VOC, was detected above the NYSDOH action level. As such, there is a complete exposure pathway for Adult and Child Visitors, Adult Commercial Worker, and Adult Utility Workers at Parcels I, III, and V. As discussed above in subsection 4.3, these concentrations of compounds were not associated with former MGP operations. These concentrations were well below the OSHA PELs for occupational workers.

6.8 QHHEA Summary

As a result of the potential complete exposure pathways to soils, groundwater, and soil vapor, any future intrusive activity should evaluate and address, as necessary, the identified pathways to COPCs for Site workers. Any future excavation can be safely managed by the current owners to address potential exposure pathways for the construction and utility worker to COPC’s in surface and subsurface soil, and groundwater.

A complete exposure pathway to chlorinated and other non-MGP VOCs within indoor air was identified during the RI. As discussed above, these compounds are not related to MGP gas operations, but are related to current use activities at Parcel I and Parcel V, and historic operations at Parcel III. The concentrations are well below established OSHA PELs. However, the TCE concentrations in the soil vapor and indoor air will require mitigation according to NYSDOH soil vapor guidance.

Potential risk for adults and children does exist for direct contact, inhalation, and ingestion of dust and surface soil. However, surface soil impacts appear to be related to the urban conditions, not the former MGP. As such, the potential risk is similar to that of any urban area.

Greater risk is associated with uncovering and having direct contact with, or ingestion of, heavily impacted subsurface soil and groundwater. Adults and children are not likely to be involved in the excavation activities required to make contact with these media. Construction and utility workers are most likely to face these risks, and appropriate soil management methods are necessary.

7. Fish and Wildlife Resources Impact Analysis (FWRIA)

This FWRIA was prepared to identify potential or actual MGP-related impacts to fish and wildlife at or near the former Fulton MGP Site. It also characterizes fish and wildlife resources and habitat at and near the Site.

Ecological studies completed as part of KeySpan's Gowanus Canal Investigation (GEI, 2009) and the USEPA Gowanus Canal RI (HDR, et.al, 2011) are not considered as part of this analysis. The findings from these investigations have not been integrated into this report because investigation and remedial actions within the Gowanus Canal will be addressed under the USEPA Superfund program.

This FWRIA contains:

- A characterization of the floral and faunal resources present and the value of these resources to the surrounding community
- Identification of applicable regulatory standards and criteria for fish and wildlife
- Evaluations of potential exposure pathways to fish and wildlife from Site-related chemicals of potential ecological concern (COPECs)
- Conclusions regarding the potential of exposure and possible impacts to fish and wildlife on or about the Site

7.1 Ecological Setting

The Fulton MGP Site includes five parcels that are described above in subsection 1.2. Thomas Greene Playground (Parcel II) is classified as open space and outdoor recreation. Thomas Greene Playground consists of paved playing courts, swimming pool area and handball courts. It is primarily paved with bituminous asphalt and concrete. Trees are present within tree wells to the east and to northwest of the playing courts. Trees within tree wells are located within the sidewalk areas of Douglass, Degraw and Sackett Street ROWs. Parcels I, III, and V are developed with commercial warehouse buildings. Parcel IV is unpaved and used as a construction staging area and storage of roll-off bins and the eastern portion of Parcel III is unpaved but is used for vehicle parking.

The Site is located in area zone for manufacturing (M2-1 and M1-2) and currently manufacturing, commercial, and dense residential uses dominate the land within 0.5 mile of the Site. The manufacturing/commercial zoned areas are covered by buildings, concrete sidewalks, and bituminous asphalt paved streets. As a result, much of the area is classified as paved road or urban structure exterior (New York State Heritage Program, 2002). The paved road category includes much of the Site, parking lots, streets, and sidewalks.

The residential areas consist of row-house style buildings surrounded with limited areas of ornamental plantings and asphalt paved streets within a ½ mile of the Site.

Little vegetation exists to support wildlife populations. Table 17 presents a summary of ecological receptors and habitat for the area.

7.2 Fish and Wildlife Resources

7.2.1 Terrestrial Resources

The United States Fish and Wildlife Service (USFWS) and the NYSDEC Natural Heritage Program were contacted regarding species of concern, significant habitats, and fishery resources within two miles of the Site. In addition, potential resources in the vicinity of the Site and surrounding 0.5-mile radius were evaluated on the ground by an ecologist.

The objectives of the terrestrial resources review were to:

- Identify, map, and describe significant ecological resources, plant communities, and aquatic resources on and adjacent to the Site
- Record evidence of stress to plants and animals, if any, from Site-related chemicals

7.2.2 Aquatic Resources – Gowanus Canal

The Gowanus Canal abuts Parcel I and the remainder of the former MGP is located within approximately 1,100 feet of the Canal. The NYSDEC classifies the Gowanus Canal as “SD”, indicating the water is suitable for fish survival.

The canal is located to the west/northwest of the Site. The canal bulkhead consists of pilings and bulkhead structures that separate adjacent upland areas from the Canal.

7.2.3 Freshwater and Tidal Wetlands

The Gowanus Canal is the only wetland identified on the USFWS National Wetland Inventory (NWI) Maps (The Narrows and Jersey City, NY-NJ quadrangles) and NYSDEC Tidal Wetland Maps (Figure 17). The Canal is mapped as an estuarine and marine deepwater wetland (E1UBLx). Shallow groundwater at the Site generally flows west/southwest towards the Gowanus Canal.

7.2.4 Fish and Wildlife Resources

Wildlife uses in the area were evaluated using literature sources and site review. General wildlife values (*e.g.*, food and cover availability) also were noted.

NYSDEC Environmental Resource data indicates that the former Fulton MGP Site is within an area where a threatened plant, Red Pigweed (*Chenopodium rubrum*), and an endangered beetle, the American burying beetle (*Nicrophorus americanus*) (Figure 17) were reported in 1890 and 1905, respectively. Their habitat does not currently exist at the Site. Correspondence with the NYSDEC Natural Heritage Group confirmed that federally listed endangered, threatened, or species of concern are not otherwise known to occur within two miles of the Site (NYSDEC Natural Heritage Group, 2011).

The surrounding two-mile radius consists of residential homes, a park with primarily paved surfaces, and industrial/commercial properties. These areas typically consist of ornamental planting interspersed with trees and shrubs; these plants are frequently introduced exotic species used for ornamental purposes. These areas do not support an abundance of wildlife because of the general lack of desired vegetation (that provides food and cover), and constant human activity. London Plane Trees (*Platanus × acerifolia)* and Maple (*Acer spp*.) trees are located in tree planters on the Site. These trees and their microhabitats do not provide significant habitat for wildlife.

7.2.5 Observation of Stress

Signs of stress to vegetation and wildlife from site-related chemicals were not observed at the Site.

7.2.6 Value of Habitat to Associated Fauna

The Site and adjoining terrestrial properties are of very little value to wildlife. The area is developed, and only small, isolated pockets of scarce vegetation exist. The wildlife expected to occur in the vicinity includes only urbanized bird and mammalian species such as mockingbird (*Mimus polyglottos*), gray squirrel (*Sciurus carolinensis*), and Norway rat (*Rattus norvegicus*).

7.2.7 Value of Resources to Humans

The Site and surrounding area has value to humans for recreational use - on paved sport areas and a concrete pool. These are of limited value to of wildlife. Bird feeders may be in the ornamental garden areas and trees in the surrounding area.

7.2.8 Applicable Fish and Wildlife Criteria and Standards

Site-specific criteria protective of fish and wildlife resources that may be applicable to future remediation are included in:

- Migratory Bird Treaty Act, which protects migratory birds, their eggs, and nests from harm. However, nesting habitat and accompanying resources are limited to absent on the Site.

7.3 Exposure Pathways Analysis

7.3.1 Chemicals of Potential Ecological Concern

PAHs, metals, and pesticides detected in shallow surface soil are considered the COPECs for this FWRIA.

For this assessment, the chemicals detected in groundwater are not considered COPECs for ecological receptors except indirectly as a potential source of contamination to surface water or sediment in the Gowanus Canal. The depth to groundwater is generally greater than 3 feet bgs, which is below the root zone of most plants. Where groundwater is less than 3 feet bgs, the area is unvegetated and/or paved. Therefore, no exposure routes exist, and the chemicals detected in groundwater are not discussed.

The majority of the Site consists of paved surfaces. Surface soil samples were collected from scarce unpaved areas and exposed soils within tree planters in Thomas Greene Playground and adjacent street ROWs. The exposed soils have little value to wildlife and pose minimal exposure risk. Nonetheless, the COPECs in surface soil are discussed below.

7.3.2 Fate and Transport

The COPECs consist of PAHs, metals, and pesticides.

PAHs - PAHs are a major component of tars. PAHs contain only carbon and hydrogen and consist of two or more fused benzene rings in linear, angular or cluster arrangements. The number of rings in a PAH molecule affects its biological activity, and fate and transport in the environment. In general, most PAHs can be characterized as having low vapor pressure, low to very low water solubility, low Henry's Law constant, high log K_{ow}, and high K_{oc}.

Although PAHs are regarded as persistent in the environment, they are degradable by microorganisms. Environmental factors, microbial flora and physicochemical properties of the PAHs themselves influence degradation rates and degree of degradation. Important environmental factors influencing degradation include temperature, pH, redox potential, and microbial species. Physicochemical properties, which influence degradation, include chemical structure, concentration and lipophilicity.

Metals – In a terrestrial setting, trace elements released to the environment accumulate in the soil (Sposito and Page, 1984). Mobility of these trace elements in soil is low and accumulated metals are depleted slowly by leaching, plant uptake, erosion, or chelation. The half-life of trace elements in temperate climate ranges from 75 years for cadmium to more than 3,000 for zinc.

The transport of trace elements in soil may occur via the dissolution of metals into pore water and leaching to groundwater, or colloidal or bulk movement (i.e., wind or surface water erosion). The rate of trace element migration in soil is affected by the chemical, physical and biological characteristics of the soil. The most important characteristics include:

- Eh-pH system
- Cation exchange capacity and salt content
- Quantity of organic matter
- Plant species
- Water content and temperature
- Microbial activity

Metals that do mobilize from the soil into the water column are most mobile under acid conditions and increasing pH usually reduces their bioavailability (McIntosh, 1992).

Pesticides –Organochlorine pesticides, specifically aldrin, dieldrin DDT and its metabolites, were widely applied throughout the United States to mitigate nuisance pests during the 1940s and 1950s (Dunlap, 1981) – post-dating the cessation of the MGP operations circa 1929. In general, organochlorine pesticides can be characterized as having low water solubility, low Henry's Law constant, high log K_{ow}, and high K_{oc}, resulting in the tendency to sorb strongly to solids and remain persistent in the environment, and hold the potential for bioaccumulation in ecological receptors.

Organochlorine pesticides are regarded as highly persistent in the environment; however, degradation of pesticides occurs via microbial and physiochemical processes. Physiochemical degradation processes include photolysis, hydrolysis, oxidation and reduction. Environmental factors, microbial flora and physicochemical properties of the pesticides influence degradation rates and degree of degradation. Organochlorine pesticides tendency to adhere to organic matter and soil clays result in these contaminants being subject to potential migration through surface run-off.

Pesticides are present in surface soil due to historic pesticide applications, since these chemicals are not related to MGP facility operations and did not come into use until after the MGP shut down.

7.3.3 Exposure Pathways

Wildlife resources in the commercial/residential area surrounding the Site are limited due to the lack of food, cover, and habitat. Paved areas block direct exposure. Also, constant human disturbance limits the population to wildlife species more tolerant of human activity. No state or federally listed species were identified as occurring on the Site.

7.4 Conclusions

The FWRIA indicates the Site and surrounding areas are disturbed urban habitat due to the developed nature of the area and limited presence of vegetation. The Site is mostly covered with buildings and asphalt. Wildlife species typically present are transient species and are adapted to the urban setting.

Due to the lack of habitat, high level of disturbance and no exposure routes to terrestrial wildlife through groundwater or soil, the potential ecological risk from COPECs in surface soil is minimal.

8. Conceptual Site Model

The Conceptual Site Model (CSM) provides a holistic framework for the physical, chemical and contaminant distribution at the Site. It serves as a basis for future decisions regarding investigation or remediation. The CSM will discuss the nature of the sources of impacts, pathways for source migration, and potential human and ecological receptors.

Sources and Pathways for Migration

Petroleum and tar impacts are present on the east side of the canal beneath Parcels I, II, III, IV, and VI. On the west side of the canal tar is present at Parcel VIII. The vertical and lateral extent of tar impacts are shown on cross-sections A-A' through E-E' in Figures 11 and 12.

Petroleum and tar saturated soils are present beneath Parcel I, where tar, oil, and naphtha tanks were used for storage of NAPL. A tar separator tank was also present there. Tar and oil tanks with overflow pipes to the canal are depicted in historic maps of Parcel 1. These are all potential sources for both subsurface impacts on Parcel I and impacts to canal sediments from the migration of residues which spilled, were discharged, or leaked from vessels, tanks and piping during the time the MGP operated.

Tar saturated soils are present beneath Parcel II next to the former holder and unidentified tanks both in fill above the meadow mat, and in and glacial outwash deposits below the meadow mat. Some tar migrated laterally atop the meadow mat to the northwest. Where the meadow mat is absent, the tar migrated downward through the more permeable glacial outwash. As the tar migrated downward, its volume decreased with depth until the driving head was insufficient to push it deeper. The deepest tar impacts were encountered as deep as approximately 128 feet bgs [elevation -120 feet] in FW-MW-11.

Tar-related impacts in the subsurface at Parcel III are apparent, both inside and outside of the former holder. Petroleum-related impacts are apparent outside the holder, at shallower depths than tar. Potential migration pathways are the same as for Parcel II.

Tar-related impacts at Parcel IV are most apparent within the former holder foundation. The foundation currently seems to be intact, but its current condition does not rule out potential leakage now or in the past. Potential migration pathways are consistent with Parcels II and III.

Parcel V is not a source area. Migration pathways from this Parcel are not a concern. There are no MGP-related impacts on Parcel V that exceed the Unrestricted Use SCO. Petroleum-impacts related to the post-MGP use of the property are present on the parcel at concentrations below the Commercial Use SCO.

Parcel VI has significant tar-related subsurface impacts, as deep as 128 feet. Since this Parcel was not part of the former Fulton MGP, the impacts are assumed to have migrated to it via the subsurface. Tar saturation and coatings are apparent in the subsurface. The potential pathways are similar to those described above. Some data support tar migration from the subsurface into canal sediments, some data support migration of tar out of the canal.

There was no evidence of NAPL observed in the Parcel VII subsurface – though tar is present in adjacent canal sediments.

The subsurface at Parcel VIII contains tar impacts, with saturation noted as deep as 41.6 feet, and sheen noted as deep as 105 feet. The primary source of these deep impacts appears to be subsurface migration from the east side of the canal. The shallowest tar impacts are about elevation -25. These are likely a result of migration from the canal sediments.

There are several *potential* sources of tar in the canal including: migration of subsurface impacts resulting from spills and/or leaks from vessels, tanks, and piping that may have occurred while the plant was operating, barging activities that may have caused releases, and the influence of flushing tunnel operations on PAHs/tar from downstream locations.

The distribution of tar in canal sediments and in nearby soils is complex and does not clearly demonstrate the direction of tar movement. At least some tar migrated from subsurface soils into the canal sediments and some may have migrated from the sediments back into subsurface soils. Flow conditions in the canal have varied significantly over the past several decades and it is possible that tar migration in both directions has taken place as a result of changes in the operation of the Flushing Tunnel. The extent and magnitude of tar in the Canal sediments was probably influenced by the former Flushing Tunnel operation, which historically drew water up the Canal from Gowanus Bay and more recently, pulled water from Buttermilk Channel on the East River and pushed water down the Canal to Gowanus Bay.

Tar in the canal sediments appears to have impacted shallow soils adjacent to the Canal in and around the bulkheads.

The extent of the observed tar-related impacts is defined by the following borings at the edge of the RI study area:

- FW-SB-39, FW-SB-40, FW-SB-42, FW-SB-52 and SB011/GCMW-011 to the north of the Fulton MGP Site
- FW-MW-05R, FW-MW-06, and FW-MW-07, on the eastern boundary of Parcel II
- FW-MW-04, FW-MW-4R, FW-SB-37, and FW-SB-38 to the south
- GC-MW-02 I, SB-02S/I, FW-SB-44, FW-SB-47, FW-SB-48 and FW-SB-50 to the west of the Gowanus Canal

While these borings bound the area of tar impacts at any depth, impacts within that area are not continuous.

At the southeastern boundary of the RI study area, an isolated lens of tar was observed in FW-SB-37 at 53 feet and elevated PAH concentrations were observed in FW-SB-38 (60 to 65 feet). Generally, soil concentrations of BTEX and total PAHs are significantly reduced, to non-detectable away from the tar sources.

Groundwater flow in the shallow zone (water table) is to the southwest. The intermediate groundwater flows to the south. Groundwater containing dissolved phase tar-related chemicals discharges to the Canal; however, volatilization, biodegradation, and dilution likely mitigate the concentrations of dissolved concentrations.

VOCs (BTEX and chlorinated) in groundwater and soils will volatilize to the vadose zone. Aerobic degradation of aromatic hydrocarbons (BTEX) will reduce the potential and likelihood for any impact to indoor or ambient air, while chlorinated VOCs unrelated to the former MGP operations may impact indoor air as they migrate through the vadose zone relatively undegraded. SVI testing at on-site buildings show that potential MGP-related impacts were found within background levels; however, chlorinated compounds have adversely affected indoor air at Parcel III.

Ecological Receptors

There is minimal risk for impacts to ecological receptors at the former Fulton MGP Site because of the lack of habitat and the transient nature of urban wildlife.

Human Receptors

As discussed in Section 6, there are potentially complete pathways for human receptors to come into contact with both MGP-related and non-MGP-related chemical compounds in subsurface soil, groundwater, soil vapor and indoor air. Under current conditions; however, these impacts pose no risk of harm to human health. Potential future utility and construction workers may contact contaminants in subsurface soils at each of the parcels and beneath the streets during excavation activities. There is a potential risk of harm to these workers performing utility repairs or future construction activities from exposure to contaminated subsurface soil, groundwater, and soil vapor.

9. Summary, Conclusions, and Recommendations

The RI was performed under the terms of the ACO Index No. A2-0552-0606 and in accordance with the NYSDEC-approved RIWP and addenda to evaluate potential impacts to soils, groundwater, soil vapor and indoor air from impacts associated with the former operations of the Fulton MGP. The MGP produced gas for use by local businesses and the nearby community between circa 1879 and 1929. Following decommissioning, the Fulton MGP was subdivided into five properties (Parcels I through V) and sold between the mid-1930s and 1940s. National Grid and its predecessors have not controlled the properties since their sale.

Summary

The Site is located adjacent to the Gowanus Canal that has been subject to over 140 years of heavy commercial and industrial uses. NYSDEC records indicate that petroleum was used, stored, and spilled at the former Fulton MGP Site and nearby properties. RI analytical data show that the former and current land use activities have impacted soil, sediment, and groundwater media at the former Fulton MGP Site and within the RI study area.

The Site and surrounding area has been subject to considerable filling that was associated with the construction of the Gowanus Canal and creation of land adjacent to the Canal, prior to the construction of the MGP. RI explorations identified foundations for former holders at Parcels III, IV, V, and former tank foundations at Parcel II. Fill materials were likely brought in following the decommissioning of the MGPs as part of the development of the properties. Alluvial and marsh deposits (referred to as meadow mat) underlie the fill. RI investigations have delineated the meadow mat deposits. Beneath these materials, in order of increasing depth, glacial outwash sands, Jameco Gravel, and bedrock were encountered.

SVOCs (primarily PAHs), PCBs, pesticides, and metals were found in surface soils at concentrations that exceed the Unrestricted Use SCOs. Pesticides, PCBs, and metals (cadmium, mercury, nickel, and zinc) are not associated with MGP operations and it is likely they are related to post MGP activities. PAHs were detected in surface soil above the Commercial Use SCOs; however, the concentrations were generally in the range of those found in surface soils in NYC, with the exception of one location (FW-SS-09) within a tree well at Thomas Greene Playground. The park is paved with bituminous asphalt pavement with the exception of tree wells.

Shallow subsurface soils (within top 5 feet) did not exhibit tar-related impacts except where sheens were observed within the holder foundation at Parcel III. Shallow subsurface soils contained PAHs and metal compounds (arsenic, barium, cadmium, copper, lead and mercury) at concentrations above the Commercial Use SCOs. PAHs and metals are commonly found in imported fill and urban areas at similar concentrations.

Deep subsurface soils (below 5 feet bgs) contained fill (including former MGP foundations), petroleum and tar impacts. Concentrations of BTEX, PAHs and metal compounds (arsenic, copper, and mercury) were detected above the Commercial Use SCOs.

Tar was observed on Parcels I (though petroleum impacts were more prevalent here), II, III, IV, VI, VIII, Tar was also observed adjacent to the western Gowanus Canal Bulkhead south of Parcel VIII at elevations above and below the native sediments of the Gowanus Canal (depending on the location). Tar-related impacts at Parcel II are present above and below the meadow mat. In most areas, tar has migrated downward through the meadow mat into the glacial outwash sands. Some of the tar has migrated laterally to the west on top the meadow mat beneath Nevins Street and Degraw Street and to Parcel III. Tar-related impacts were encountered as shallow as 5 feet bgs and as deep as 105 feet bgs at Parcel II and within the adjacent Nevins and Degraw Street ROWs. These impacts are below buildings, asphalt paving, and streets.

Tar impacts at Parcels III and IV are present within the holder foundations. Subsurface data outside the holders at Parcels III and IV are limited due to the presence of the overlying building and active businesses. Therefore, the extent of impacts cannot be precisely determined.

Parcel V is not a source area. There are no MGP-related impacts on Parcel V that exceed the Unrestricted Use SCO. Petroleum impacts related to the post-MGP use of the property are present on the parcel at concentrations below the Commercial Use SCO.

Tar is present in native sediments beneath the Gowanus Canal and along the eastern and western bulkheads. There are several *potential* sources of tar in the canal, including subsurface migration from the landside parcels, migration of residues from incidental spills taking place during the time period of plant operations, and the influence of flushing tunnel operations on PAHs/tar from downstream locations.

The distribution of tar in canal sediments and in nearby soils is complex and does not clearly demonstrate the direction of tar movement. At least some tar migrated from subsurface soils into the canal sediments and some may have migrated from the sediments back into subsurface soils. Flow conditions in the canal have varied significantly over the past several decades and it is possible that tar migration in both directions has taken place as a result of changes in the operation of the Flushing Tunnel. The extent and magnitude of tar in the Canal sediments was probably influenced by the former Flushing Tunnel operation, which historically drew water up the Canal from Gowanus Bay and more recently, pulled water from Buttermilk Channel on the East River and pushed water down the Canal to Gowanus Bay.

In the vicinity of the Site, potable water is provided by the NYC. Dissolved phase groundwater impacts in the shallow (water table) portion of the Upper Glacial Aquifer are discharging toward the Gowanus Canal. Dissolved phase groundwater impacts in the intermediate zone of the Upper Glacial Aquifer are generally less than the water table impacts and flow roughly southerly. The intermediate zone groundwater has an upward flow component that likely results in dissolved phase impacts moving into the water table portion of the Upper Glacial Aquifer. The deep zone of the Upper Glacial Aquifer and the underlying Jameco Aquifer are likely not impacted by MGP operations, but do exhibit the presence of dissolved phase constituents consistent with fuels and chlorinated solvents.

A QHHEA was completed to evaluate potential exposure pathways to Site-related COPCs in soils, groundwater, and soil vapor. The QHHEA determined that:

- Potential exists for adult/child, trespasser, and construction/utility worker to contact PAH above the Commercial SCOs in surface soils. Limited areas of exposed surface soils are present in tree wells in Thomas Green Playground and street ROWs. Exposed areas of surface soils are present at Parcels I, IV, and VI. PAH concentrations in surface soils were generally in the range of background concentrations surface soils in NYC with the exception of one sample in Thomas Greene Playground.

- Adult/child visitors, utility/construction workers, and trespassers at Parcels III and V have a potential to encounter non-MGP-related VOCs in indoor air. The concentrations of TCE and other chlorinated VOCs were detected above the NYSDOH air guidelines. Based upon NYSDOH guidelines, mitigation of these non-MGP impacts may be required by the property owners.

- Potential future utility and construction workers may come into contact with COPCs in subsurface soils, groundwater, and soil vapor during intrusive activities if soils and groundwater are disturbed.

- Potential exists for adult/child, trespasser and construction/utility worker to come into contact with fugitive dust and vapors during intrusive activities within impacted soils and groundwater are disturbed.

The Step I FWRIA determined that due to the low habitat value, the high degree of paved surfaces, and the general lack of terrestrial flora and fauna, subsurface impacts associated with the former MGP pose little risk to the ecology. The FWRIA did not contemplate potential impacts to fish and fauna of the Gowanus Canal from groundwater impacts from the Fulton MGP Site as the Gowanus Canal is being investigated and remediated under the direction of USEPA as part of Superfund Site activities.

Conclusions

The objectives of the RI have been fulfilled and the nature and extent of MGP-related impacts at the Site have been adequately defined.

GEI, on behalf of National Grid, has already used the RI data and information to develop a Pre-Design Investigation (PDI) Work Plan to gather additional data to support design of a barrier wall along the canal. Regardless of sources and mechanisms of emplacement, the wall is intended to prevent migration of NAPL into or out of the canal. The PDI work plan has been approved by NYSDEC.

Recommendations

Following NYSDEC and NYSDOH approval of this report, we recommend that a FS be prepared for Parcels I through VIII, with the exception of Parcel V, to evaluate the potential remedial approaches for the Site.

Parcel V does not exhibit soil, groundwater, or soil vapor impacts related to the former MGP operations. Therefore, we recommend no further action for Parcel V.

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